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ENFOR Project C-130

Bin and Silo Design for Biomass Materials

Phase I

by

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ABSTRACT

Flowability tests were carried out on biomass materials (primarily hog fuel, wood chips and sawdust samples as well as several tests on peat, shavings and grain dust) using specially designed test equipment. Critical bin parameters to avoid flow problems were determined from the test results.

Results show that mass flow bin design, which is characterized by smooth, steep hopper walls, is necessary to avoid discharge problems. Steel and concrete had very high wall friction against the biomass samples tested, and hence, would require impractically steep hopper walls for mass flow. Ultra high molecular polymer (UHMP) had the lowest wall friction, followed by glass; both of these materials as liners will permit use of practical hopper wall angles. None of the wall materials tested were suitable for mass flow hopper design for peat because of very high wall friction.

Minimum mass flow outlet dimensions required under "instantaneous" consolidation, ie., continuous discharge without rest periods, were practical for the majority of samples tested. Except for wood chips, all of the biomass materials gained in strength during time consolidation and, hence, would require considerably larger openings to ensure reliable flow following storage at rest. In the case of hog fuel, impractically large outlet sizes would be required in order to allow for time consolidation. Hence, where storage at rest is necessary, external activation to initiate flow is recommended. Alternatively, the bin can be discharged continuously at a slow rate and material recycled into the bin.

Sawdust also gained considerably in strength following time consolidation. However, the bin outlet sizes necessary to allow for the increased strength are still practical.

Peat, unlike other biomass materials, can be discharged successfully from a funnel flow bin, but only under "instantaneous" storage. Mechanical discharge will be necessary following periods of storage at rest if the outlet size is to be practical.

Tests at below freezing on hog fuel show that gravity discharge alone is not feasible and some form of flow assistance will be necessary.

EXECUTIVE SUMMARY

A 76 cm diameter annular ring shear cell and a 61 cm diameter wall friction tester, both suited to carrying out flowability tests on biomass materials were designed and constructed during the first year of the project. The test equipment was used to obtain flow properties of biomass materials. All of the tests were done on biomass samples obtained from pulp mills and sawmills located in B.C.

Altogether, 45 series of shear and wall friction tests were done: 19 on hog fuel, 12 on wood chips, 8 on sawdust, 3 on peat, 1 on shavings and 2 tests on grain dust. Four of the tests on hog fuel and one test on chips were done at below freezing temperatures. Results of the tests were used to determine critical bin parameters to be exceeded to avoid flow problems.

Results show that mass flow bin design is necessary in order to avoid flow problems. Mass flow bins are characterized by smooth, steep hopper walls to ensure that the material slides over the bin wall in preference to funnelling over itself; "first-in-first-out" flow pattern results. However, the wall friction of conventional bin wall materials (steel and concrete) against the majority of biomass materials was found to be very high and would require very steep or impractical hopper wall angles for mass flow design. Ultra high molecular polymer (UHMP) and glass as liners had considerably lower wall friction, thus permitting acceptable hopper wall angles. The exception was peat for which none of the wall materials tested had an acceptably low wall friction, making mass flow design impossible with these wall materials.

Use of concrete as a mass flow wall material for biomass is not recommended. The use of mild or stainless steel will require very steep walls for conical hoppers and in most situations will be impractical. Since plain-flow hoppers (hoppers with slotted outlets)

require wall slopes that are 10 to 12 degrees less steep, such hoppers made out of steel will be marginally acceptable and may be used where conditions permit. With mild steel, however, wet material must not be stored at rest since corrosion on the walls could sufficiently deteriorate the surface to prevent mass flow from developing.

UHMP is recommended as a liner for plain-flow hoppers with flat sides because of the ease of installation compared with curved surfaces. UHMP with its very low wall friction is recommended for retrofitting of existing bins experiencing flow problems since many of these bins will have the necessary minimum hopper wall slopes. Special attention must be paid to fastening of the material to steel or concrete.

Glass lined bins are available with the liner material fused to steel, hence avoiding problems of fastening. Also glass lined bins have been used for many other materials (eg. grain and coal) with good results.

Under "instantaneous" consolidation, ie., continuous discharge without rest periods, and moderate to high moisture contents (25 to 70%), the minimum outlet dimensions required for mass flow bins to avoid bridging are within the range the forest industry is used to for the majority of biomass samples tested. Minimum mass flow outlets for hog fuel ranged from 1.4 meters to 3.3 meters (conical hopper *), the majority of outlets requiring less than a 3 meter mass flow opening. The majority of chip samples required outlets of less than 2 meters and the majority of sawdust and peat samples required mass flow outlets of less than 1 meter; however, as explained earlier, mass flow is not feasible for peat with the wall materials tested. Hence, gravity discharge is feasible under "instantaneous" consolidation and above freezing temperatures for most biomass materials. (At very low moisture content - less than 10% - biomass will require very large openings because of very low bulk density.)

* Note: the equivalent minimum slotted outlets are:
width = approximately half the diameter of conical outlet
length = 3 times the width

Hog fuel was, however, found to gain in strength considerably when stored "at rest" requiring very large outlet sizes to prevent bridging. Hence, where storage at rest is necessary, it is recommended that the bin be discharged continuously at a slow rate and the material recycled into the bin. Alternately, some external means of flow activation can be used to initiate flow of hog fuel following periods of time consolidation.

Wood chips did not gain in strength during time consolidation, hence, storage at rest will not require a larger opening or external means of flow activation as in the case of hog fuel.

Sawdust gained its maximum strength during the first 20 hours of time consolidation and, hence, an outlet sized to allow flow after 20 hours of storage at rest will permit flow even after longer rest periods. The minimum outlet necessary to allow for time consolidation is still quite reasonable (approximately 2 m for a conical hopper and 1 m x 3 m for a slot opening).

Peat, unlike other biomass materials, had very low shear strength and would require considerably smaller mass flow outlets, provided a suitable bin wall material could be found. Also, funnel flow is feasible under "instantaneous" conditions for dry peat (less than 60% moisture) because of its lower internal friction. Peat however, gained strength very rapidly during time consolidation and will require mechanical discharge following storage at rest. It is recommended that a suitable bin wall material or liner be sought or developed to enable mass flow bin design for peat.

Tests at below freezing temperatures on hog fuel indicated that gravity discharge on its own is not feasible and some form of flow assistance will be necessary. In the case where the material against the walls freezes with the central core remaining unfrozen, a likely scenario because of its excellent insulation properties, the result will be non-mass flow as the material will be funnelling over itself as opposed to sliding along the walls. Hence, material can be expected to pipe ("rat-hole"). Hence, precautions must be taken to prevent freezing along the walls by insulation or external heating of the bin walls.

Prior to the design of a storage bin for a biomass material, flowability tests on representative samples of the biomass are recommended, because of the variability of biomass, to ensure that flow problems do not arise.

In order to realize the full potential of mass flow bin design and avoid flow problems, some precautions to bin-feeder system design are essential:

- feeder design must ensure that the outlet is fully effective, ie., material is drawn uniformly across the whole outlet.

- fasteners and other bin accessories must not protrude into the bin as these can obstruct mass flow.

INTRODUCTION

The diminishing of world petroleum reserves has made the development of alternative, domestic energy sources an important part of Canada's drive towards energy self-sufficiency. The Canadian forests are a potential source of perpetually renewable fuels and chemicals. To promote increased utilization of biomass, the Canadian Forestry Service started the ENFOR R & D program in 1978 aimed at securing the necessary knowledge and technical competence. The program consists of two sub-programs:

1. The Production Program which is concerned with forest oriented matters such as biomass inventory, silviculture, harvesting and environmental impacts.

2. The Conversion Program which is concerned with the transformation of the biomass to energy, prepared fuels in various forms as well as chemicals.

Operation of pilot-scale biomass energy conversion plants revealed serious problems in the materials handling area and as a result, emphasis was placed on R & D aimed at solving these problems. A major materials handling problem has been reliable and uniform discharge of biomass from storage bins and silos. Stoppages in flow are common, resulting in disruptions to the operation of energy conversion plants.

Most biomass storage bins and silos rely on gravity to discharge their contents. Often, external devices are used to assist flow and to overcome flow problems. Common flow problems (illustrated in Figure 1) are:

a) Bridging

Material forms a stable arch at the outlet when the outlet is not large enough. This leads to a complete stoppage in flow (Figure 1(a)).

b) Funnel Flow (or Core Flow)

Flow takes place by the upper layers funnelling to the centre and then down the moving core (Figure 1(b)). Core flow occurs when the walls of the hopper are not steep or smooth enough. A first-in-last-out pattern of flow results in stagnant zones along the walls. A funnel flow hopper requires a considerably larger outlet than a mass flow hopper to avoid formation of a stable pipe ("rathole") and to enable complete emptying of the bin.

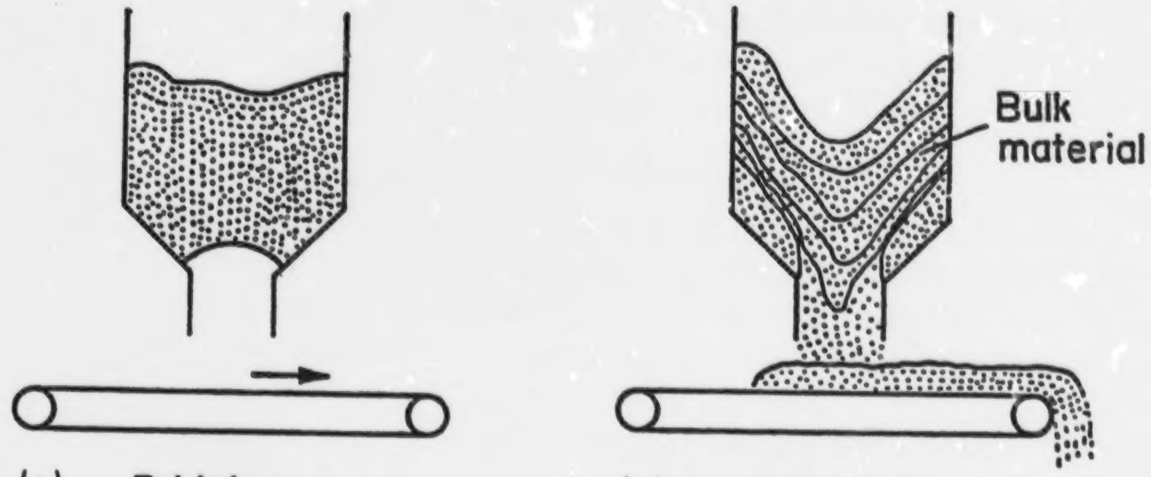
c) Piping

When a funnel flow hopper has an outlet smaller than the critical "piping" dimension, a stable pipe or "rathole" forms. Piping severely reduces the live capacity of a bin.

The majority of biomass storage bins currently in use suffer from varying degree of piping.

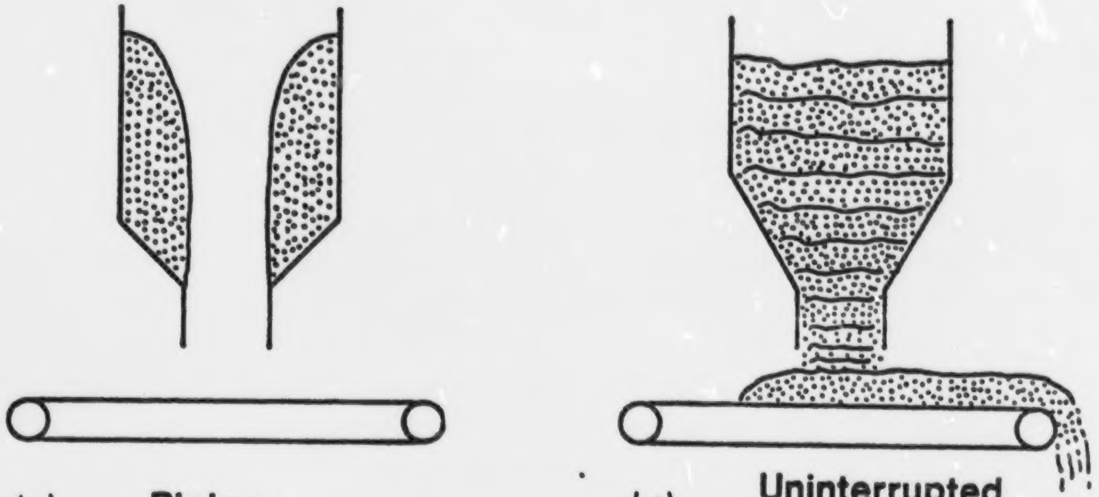
Figure 1(d) shows the ideal bin in which uninterrupted mass flow occurs. The hopper is sufficiently steep and smooth to enable the material to preferentially slide over the hopper wall rather than over itself. The material moves down the bin as a solid mass with little relative movement between the particles; "first-in-first-out" flow pattern results. A mass flow bin requires a considerably smaller outlet than a funnel flow bin to avoid bin discharge problems.

Bin discharge problems of biomass materials are primarily a result of improper bin designs. While considerable advances have been made in the design of storage bins for finer bulk materials (1), little theoretical data has been available on the flow characteristics of biomass. Hence, storage bins which have been designed with empirical methods and past experience have not performed satisfactorily and in some cases have experienced severe flow problems.


Bulk material

(a) Bridging

(b) Funnel flow



(c) Piping

(d) Uninterrupted mass flow

Figure 1 FLOW PATTERNS IN A STORAGE BIN

The majority of biomass bins and silos currently in use have adequately sized outlets to permit flow from mass flow hoppers. The flow problems however result from the fact that hoppers are non-mass flow.

In April 1980, B.C. Research was awarded a two-year contract as part of the ENFOR program to design and construct suitable flow testing equipment for biomass materials, to carry out extensive tests on biomass materials and to develop guidelines for biomass bin designs.

The first year of the project was spent on the design, construction and preliminary testing of special flow testing equipment suitable for biomass materials. During the second year, extensive tests were carried out on biomass materials using the special test equipment.

The project is currently in its third year during which a pilot scale experimental bin will be designed and constructed according to design criteria obtained from the tests on biomass. Discharge of biomass from the bin will be observed.

MATERIALS AND METHODS

FLOW TESTING EQUIPMENT

The available flow testing equipment (1,2) is not suitable for the majority of biomass materials because of their much larger particle size in comparison to common bulk materials. Hence, it was necessary to design and construct two special pieces of larger test equipment. In other respects, the test equipment that was built is similar to equipment that has been used successfully for a number of years for finer bulk materials.

76 cm (30 in.) Ring Shear Cell

The design of the Ring Shear Cell (RSC) is similar in principle to the Portishead Ring Shear Cell designed by the Central Electrical Generating Board (CEGB) in the U.K. (2). The CEGB equipment with its 25 cm (10 in.) diameter cell is suitable for testing bulk material with a top particle size of 6 mm. The new RSC built has a 76 cm diameter cell and is suitable for a maximum particle size of 25 mm. This limitation on the top particle size was necessary for practical reasons. Although many biomass materials do contain particles larger than 25 mm, results obtained from testing of minus 25 mm biomass will be equally applicable to materials containing larger size particles. The coarse particles in a bulk material act as passive agents, that is, they have little effect on the flow characteristics of the material. The fines, however, help to bind the material and develop cohesive strength. Hence, the effect of screening out the oversize (plus 25 mm) particles prior to testing is that the results will be somewhat conservative.

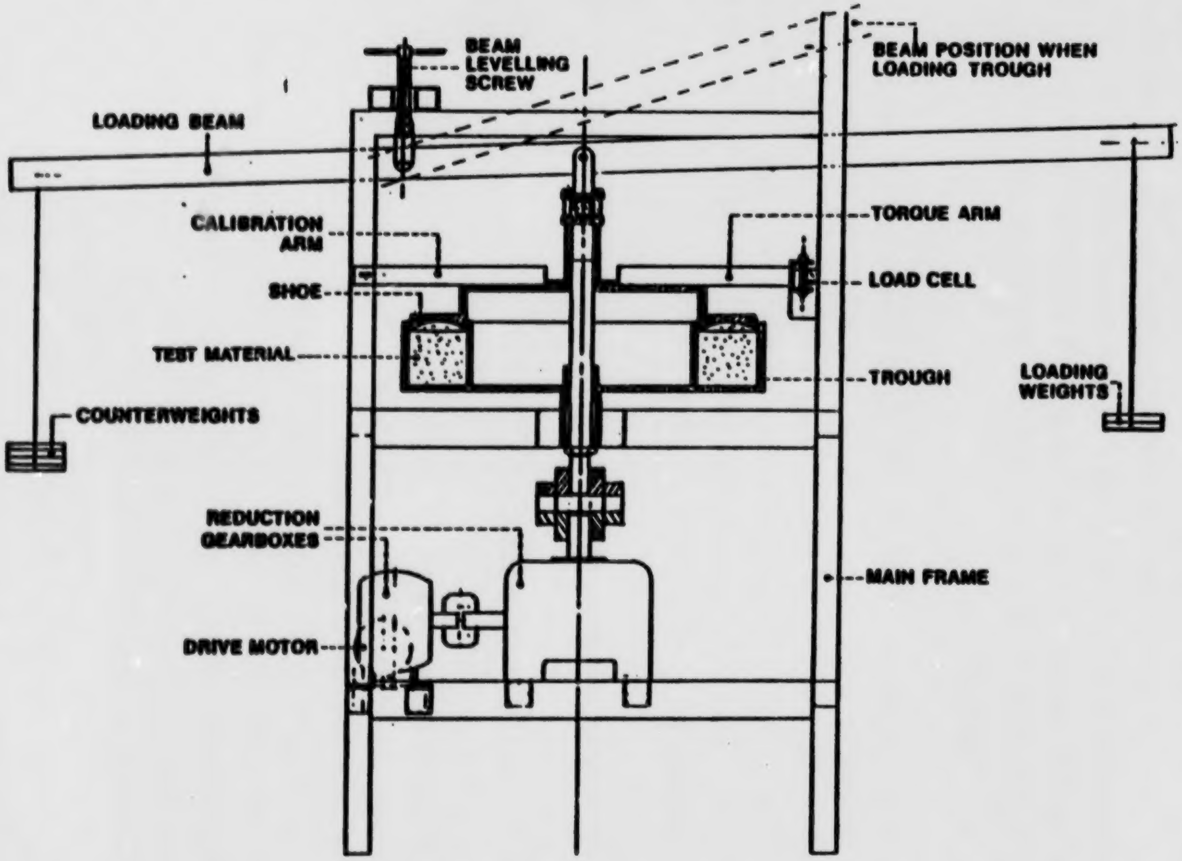
Figure 2 shows the drawing of the RSC. The cell essentially consists of an annular trough 76 cm O.D., 12.7 cm wide and 12.7 cm deep. The trough, which is filled with the test sample of biomass is covered by an annular shoe, the underside of which is recessed and has ten equispaced radial vanes which dig into the sample. The cell is mounted on a 38.1 mm diameter shaft which is driven at a rotational speed of 0.5 revolution/hour by a geared motor via two gear reducers. The shoe is suspended off a rectangular-section hollow beam which has hangers at both ends. The beam is pivotted at the bottom of a levelling screw which can be raised or lowered to ensure that the beam is horizontal during tests. The normal load on the test material is applied via the shoe by placing appropriate weights on either the loading hanger or the counter-weight hanger. The loading hanger is used for applying weights on the test material in excess of the weight of the shoe (114 kg); weights on the counter-weight hanger remove a portion or all of the weight of the shoe for tests at low normal loads. The addition of more weight will raise the shoe to facilitate filling or emptying the cell.

The shoe is held concentric, relative to the shaft and the cell, by a collar with a bronze bushing attached to the shoe. A clearance of 1.59 mm (1/16 in.) between the cell wall and the shoe and a slight taper on the outside of the shoe wall reduces the possibility of any jamming of test material between the cell and the shoe. The top of the shoe has a radial torque arm, one end of which acts on a load transducer mounted on the main frame of the equipment. The other end of the torque arm has a cable attached to it and can be linked to a calibrating mechanism in order to apply a range of known weights to the load cell.

With test material in the cell and the shoe placed in position on top of the material, the radial vanes in the shoe grip the sample by digging into the material. When the cell is rotated, the shoe is held from rotating by the radial torque arm held against the load transducer, thus causing the test material to shear. The shear strength is measured continuously from the output of the load transducer.

Frictional forces have been kept to a minimum and can be measured accurately. Rotational friction is negligible provided the shaft and the collar on the shoe are clean and well lubricated.

Figure 2 76 cm RING SHEAR CELL


BEAM LEVELLING SCREW
BEAM POSITION WHEN LOADING TROUGH
LOADING BEAM
CALIBRATION ARM
TORQUE ARM
LOAD CELL
SHOE
TEST MATERIAL
TROUGH
LOADING WEIGHTS
COUNTERWEIGHTS
REDUCTION GEARBOXES
MAIN FRAME
DRIVE MOTOR

Vertical friction of the collar along the shaft is also critical since this affects the normal load on the test material. All pivot points on the beam and the shoe collar have been equipped with bearings to minimize vertical friction and permit free movement of the shoe along the shaft. The vertical component of the friction can be determined by counter-balancing the known weights of the shoe and beam; any additional weight needed to move the shoe is a result of friction. The vertical friction is negligible when the shaft and collar are clean and well lubricated.

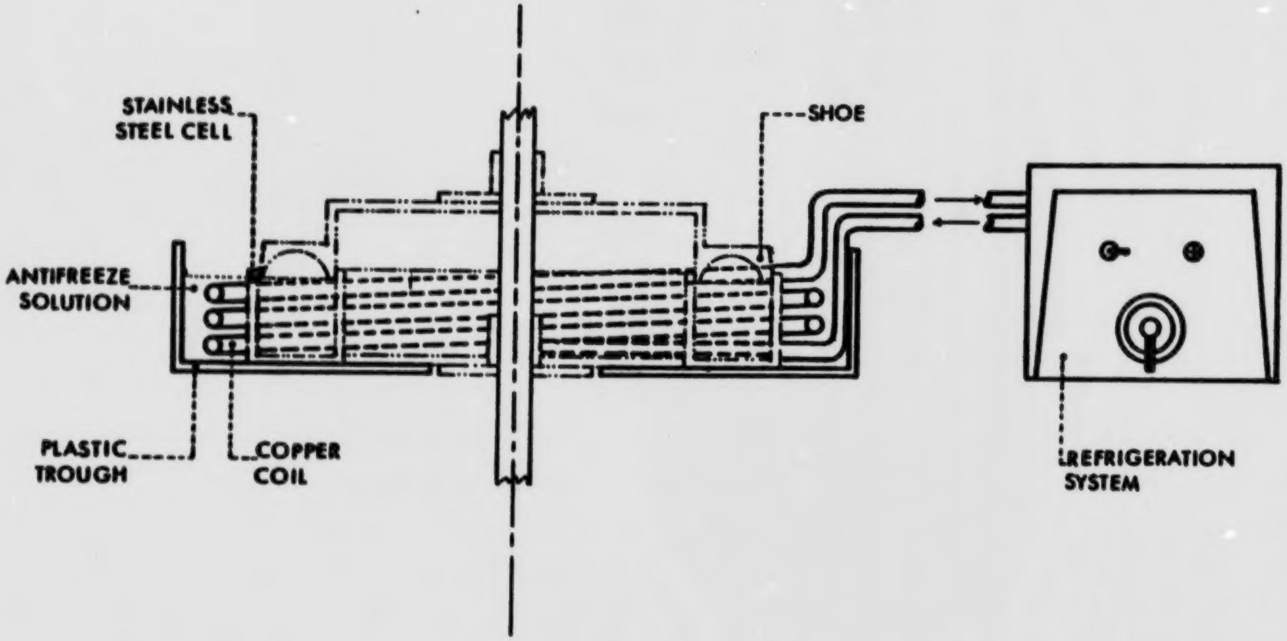
Towards the end of January 1982, a cooling system was added to the equipment to enable shear tests to be carried out at below freezing temperatures. The outside of the cell was surrounded by a reservoir of anti-freeze solution into which a refrigeration coil was immersed (see Figure 3). The cooling system is capable of maintaining the test sample of biomass at a temperature of about -5°C.

The Ring Shear Cell has been designed to be operated by one person.

61 cm (24 in.) Wall Friction Tester

The wall friction tester was considerably simpler in design than the Ring Shear Cell as shown in Figures 4 and 5. The tester consists essentially of a low speed geared motor travelling horizontally on a threaded rod (Figure 4). A load transducer mounted on a steel plate moves with the motor via two steel rods. Bearings on the motor shaft and the threaded rod prevent transferring axial loads on to the motor. The load transducer has a hook bolted to it which pulls a cable attached to an aluminium ring 61 cm (24 in.) in diameter and 10.16 cm (4 in.) deep. The ring is filled with biomass and rests on a sample of bin wall material. Normal load is put on the sample of biomass in the form of a series of plates which are placed on the cover. As the test material is dragged on the sample of bin wall material, the friction against the wall material obtained from the output of the transducer is continuously recorded. The motor is capable of pulling loads in excess of 200 kg.

Figure 3 COOLING SYSTEM FOR RING SHEAR CELL


STAINLESS STEEL CELL
SHOE
ANTIFREEZE SOLUTION
PLASTIC TROUGH
COPPER COIL
REFRIGERATION SYSTEM

The wall friction tester has a calibration system essentially consisting of a cable attached to the hook on the transducer. The hook is tensioned by a series of weights on a lever system with a multiplication factor of up to 7.

Portishead Ring Shear Cell

For finer biomass (sawdust, sander dust, peat, etc.), existing test equipment with smaller cells was used.

The Portishead Ring Shear equipment has a cell with an annular trough 5.7 cm wide and 26.7 cm external diameter and is suitable for testing material up to minus 6 mm (1/4 in.) particle size. The equipment which is described in more detail by Carr and Walker (2) has been used for over 15 years for flowability testing and has been found to be very satisfactory.

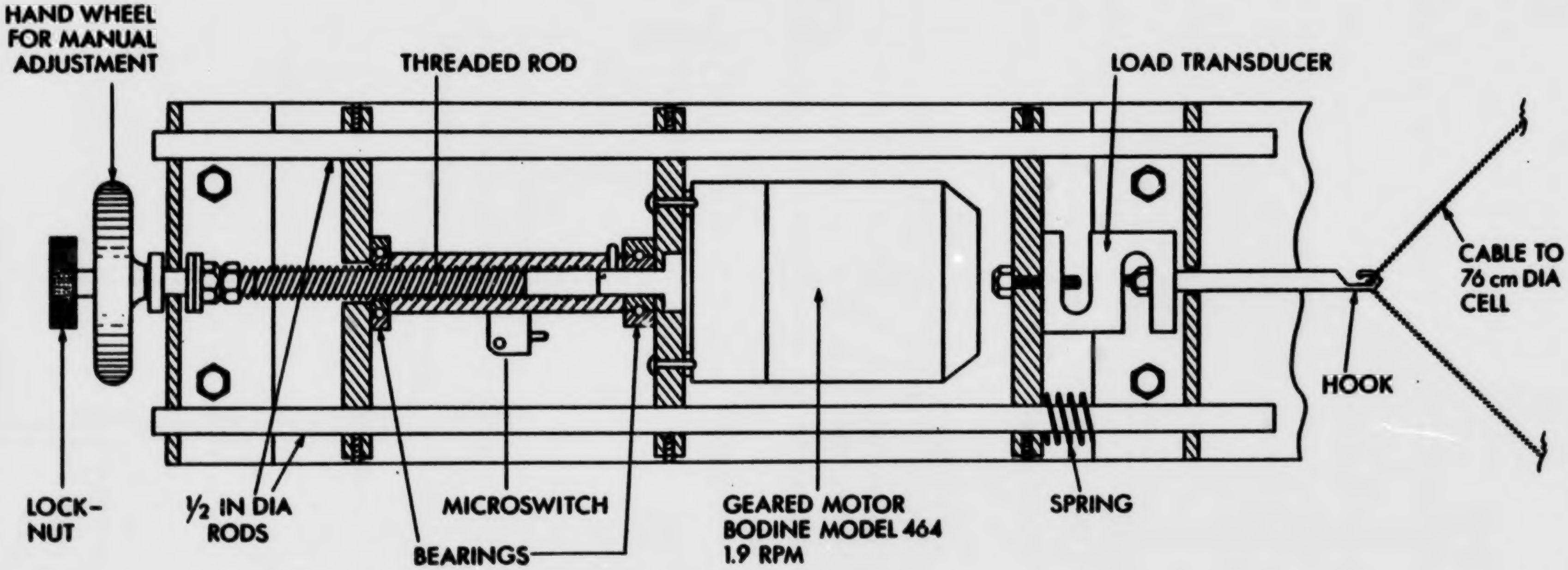

HAND WHEEL
FOR MANUAL
ADJUSTMENT
THREADED ROD
LOAD TRANSDUCER
CABLE TO
76 cm DIA
CELL
HOOK
LOCK-
NUT
½ IN DIA
RODS
MICROSWITCH
BEARINGS
GEARED MOTOR
BODINE MODEL 464
1.9 RPM
SPRING

Figure 4 PULLING MECHANISM FOR WALL FRICTION TESTER

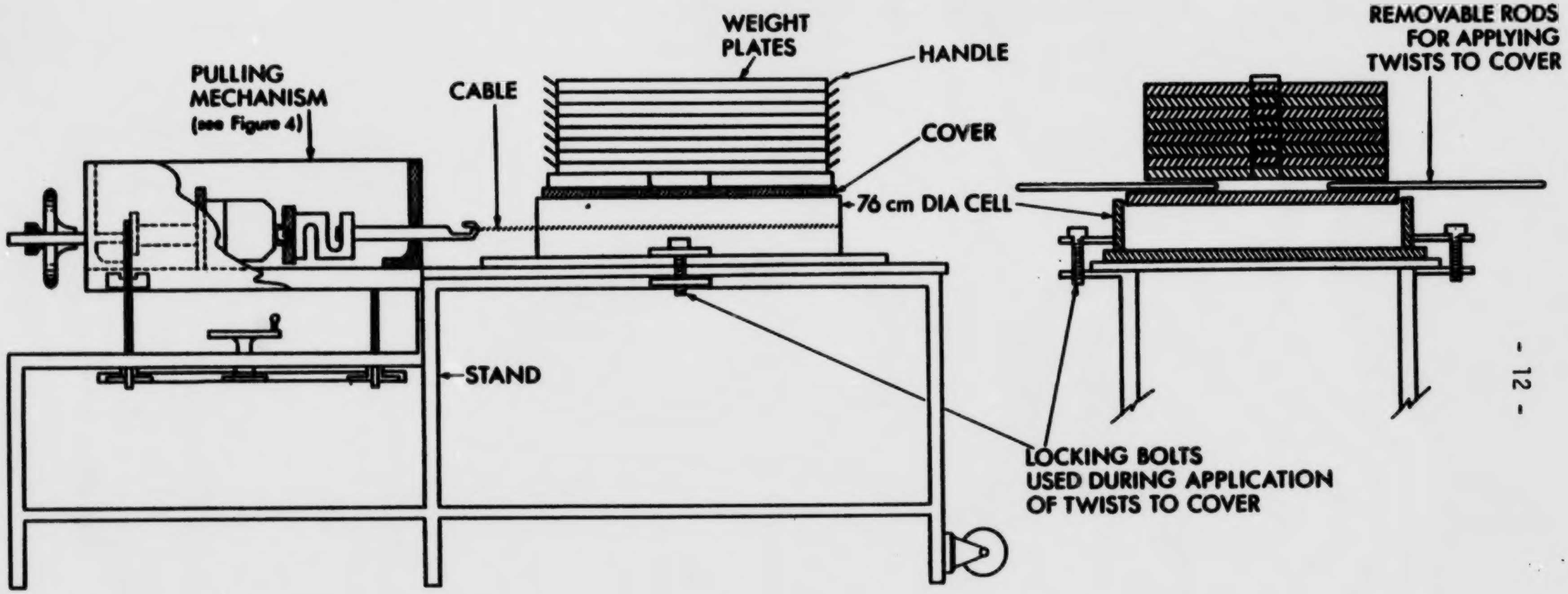

PULLING
MECHANISM
(see Figure 4)
CABLE
WEIGHT
PLATES
HANDLE
COVER
76 cm DIA CELL
STAND
REMOVABLE RODS
FOR APPLYING
TWISTS TO COVER
LOCKING BOLTS
USED DURING APPLICATION
OF TWISTS TO COVER

Figure 5 WALL FRICTION TESTER

Jenike Flow Factor Tester

The Jenike equipment (1) was used for wall friction tests on fine biomass because of convenience of preparing bin wall material samples which are required in about 12 cm squares.

TEST PROCEDURES

Flowability tests were done on samples of biomass materials obtained from mills in B.C. Altogether, 45 tests were done: 19 on hog fuel, 12 on chips, 8 on sawdust, 3 on peat, 1 on shavings and 2 on grain dust.

Most of the tests were done at ambient temperatures (16°C to 22°C) in B.C. Research's pilot plant area. Five tests were done at below freezing temperatures. Tests were done under "instantaneous" consolidation conditions (representing conditions of continuous flow) as well as "time consolidation" conditions to assess the effects of "storage at rest" when no material is withdrawn from a bin for specific periods of time.

Sample Preparation

Prior to testing, all the biomass samples were screened to remove oversize material - above 6 mm particle size for fine biomass and above 25 mm for the rest.

Shear Tests

"Instantaneous" consolidation

Following screening to remove the oversize material, the sample of biomass was thoroughly mixed to ensure uniformity and then the trough of the Ring Shear Cell was filled with the sample. Precautions were taken to avoid size segregation of the sample during filling of the cell. Most biomass materials compact considerably under load and, hence, it was necessary to fill the cell to the top. (Further topping up with test sample was sometimes necessary after tests at high loads). The shoe was placed on top of the biomass for shear tests.

Measurement of the shear strength involves a two-step procedure. The sample in the cell is first consolidated (compacted) at a given normal load corresponding to the desired consolidation stress. This is the preparation stage. A yield point at the consolidation stress is then determined by shearing the test material at a normal stress which is less than or equal to the consolidation stress.

In the Ring Shear Cell, consolidation of the material takes place under shear. (Preconsolidation is not necessary as in the Jenike Flow Factor Tester as unlimited displacement is available). The appropriate normal load is placed on the shoe and the cell rotated in the forward direction (anticlockwise). As the loosely packed material in the cell starts to shear, it gains in strength and reaches a maximum steady state strength. At this point, the material is fully consolidated. A typical shear strength vs time curve is shown in Figure 6(a). The direction of rotation of the cell is then reversed to remove all the strain in the material, that is, until the shear stress drops to zero. A normal load of less than or equal to the consolidation stress is now placed on the shoe and the cell is made to rotate forward until a fairly sharp yield point, Figure 6(b), is obtained. The maximum stress recorded gives one yield point at the appropriate consolidation stress. The shoe is raised off the cell, the material is stirred up and the above procedure is repeated for another yield point either at the same or a different consolidation level.

For most biomass samples, 7 yield points were determined at each level of consolidation, and tests were done at 6 consolidation levels. Hence, 42 yield points were determined for each sample. Figure 7 shows the typical results of shear tests illustrated as yield loci.

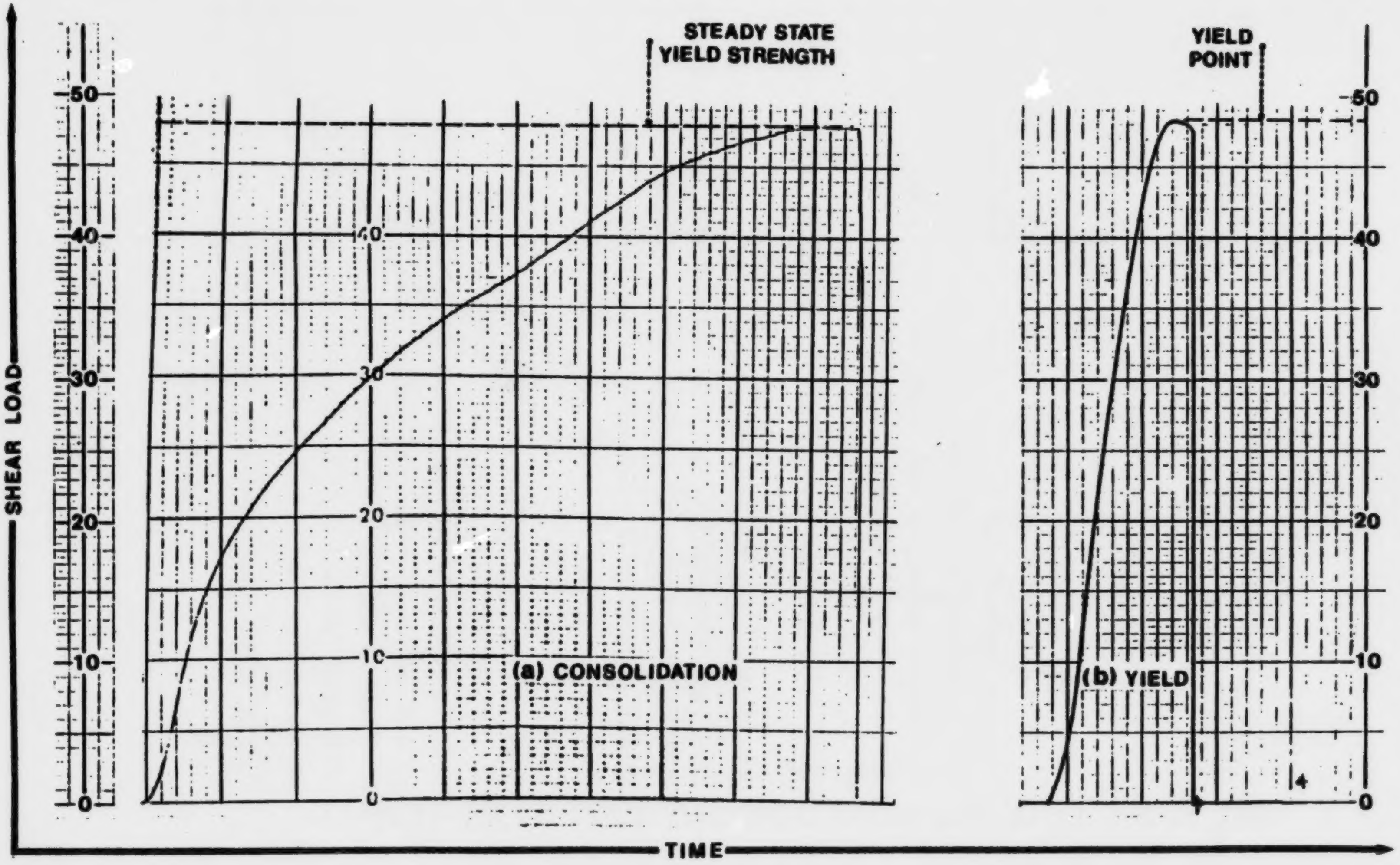
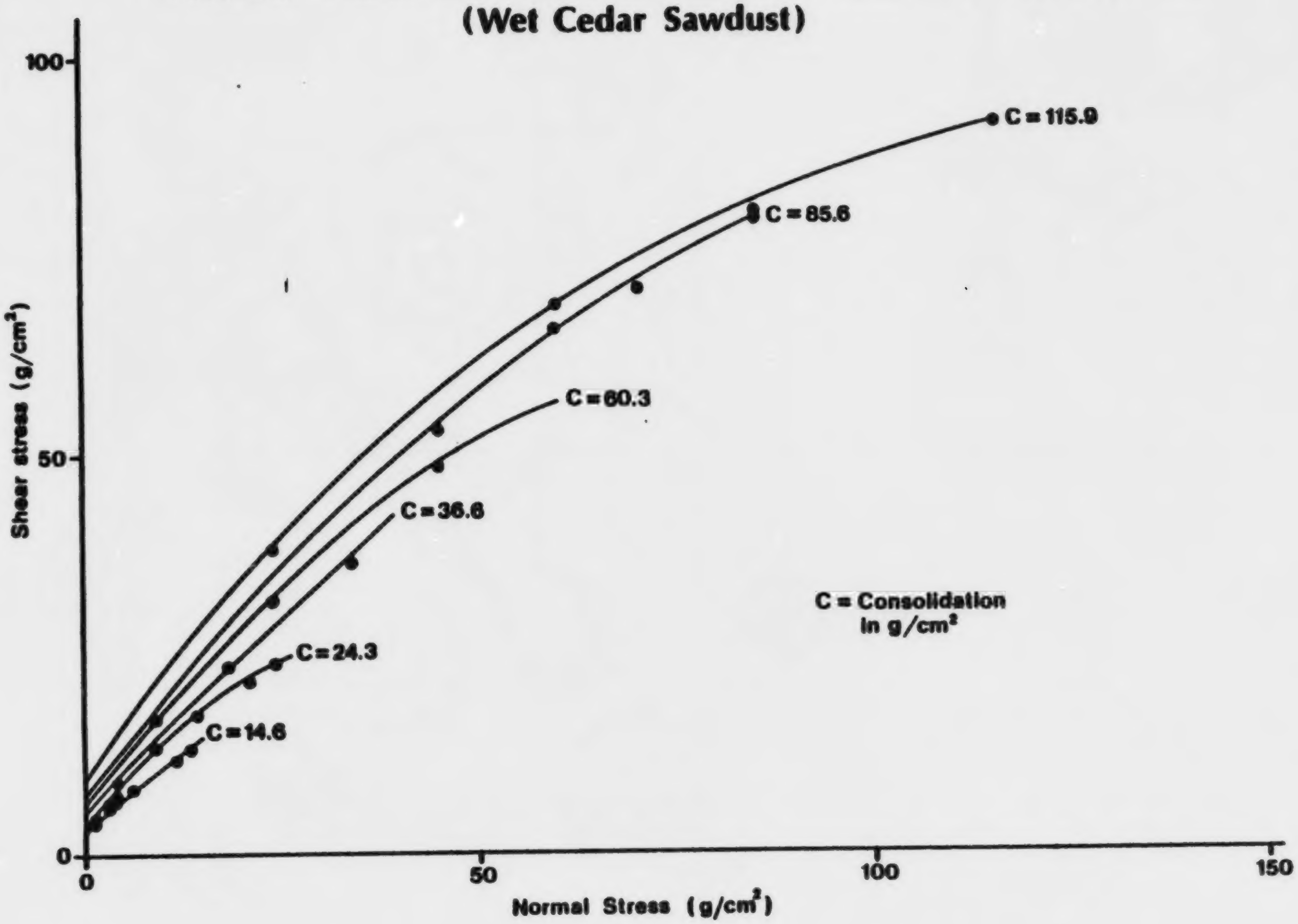


Figure 6 CONSOLIDATION & YIELD POINT DETERMINATIONS

Figure 7

TYPICAL YIELD LOCI OBTAINED FROM THE RING SHEAR CELL
(Wet Cedar Sawdust)



Time consolidation

The test procedure described above is for "instantaneous" consolidation, ie. the yield point of the material is determined immediately following consolidation. When a material is allowed to consolidate for a period of time (Time Consolidation Test) often it gains in strength. This gain in strength is equivalent to deterioration of flowability during storage at rest in a bin.

Time consolidation tests were done on biomass samples for periods ranging from a few hours to several days. Unlike "instantaneous" tests where 42 yield points were determined for a given biomass sample, only one yield point per yield locus was determined for a selected number of yield loci because of the time factor. In order to avoid tying up the equipment for long periods of time, tests were done over lunch periods, overnight, as well as over weekends.

Time consolidation data were interpreted in conjunction with instantaneous data. The limited amount of data obtained made time consolidation tests particularly sensitive to "bad points" making it necessary to take special care in interpretation of results; some judgement had to be exercised when rejecting bad points.

The procedure followed for time consolidation tests is as follows.

Material was consolidated at a given normal load as explained above for instantaneous tests. When steady state shear stress was obtained, the cell was reversed to remove all the strain from the material. The sample was then left for a prescribed period of time following which the yield point of the sample was determined at the same load as the consolidating load. The reason for using the same load was to avoid disturbing the test material by changing weights.

Tests at below freezing temperatures

Shear tests were also done on the large ring shear cell on 4 samples of hog fuel and 1 sample of wood chips at approximately -5°C. The plastic trough outside of the cell was filled with antifreeze solution and cooled by the refrigeration coil. At the same time, the test sample of biomass (wrapped in a plastic bag) was precooled by leaving it in a freezer overnight. When the test sample and the antifreeze had cooled sufficiently, the sample was placed in the cell. Excessively moist samples which tended to freeze up into large lumps were broken up and reduced to individual pieces prior to their placement in the cell.

Shear tests were done under instantaneous and time consolidation conditions as described previously for ambient temperatures.

Wall Friction Tests

The following samples of bin wall materials were used during wall friction tests:

- mild steel, mill grade with scale on
- stainless steel, mill grade
- concrete, form finished
- ultra high molecular polymer (UHMP) liner
- plastic coating
- glass

Tests on mild steel, stainless steel and UHMP were done for all biomass samples. Tests on the remaining wall materials were done for a selected number of biomass samples; results obtained, however, will be indicative of similar biomass materials.

Testing procedure for the 76 cm wall friction tester was as follows.

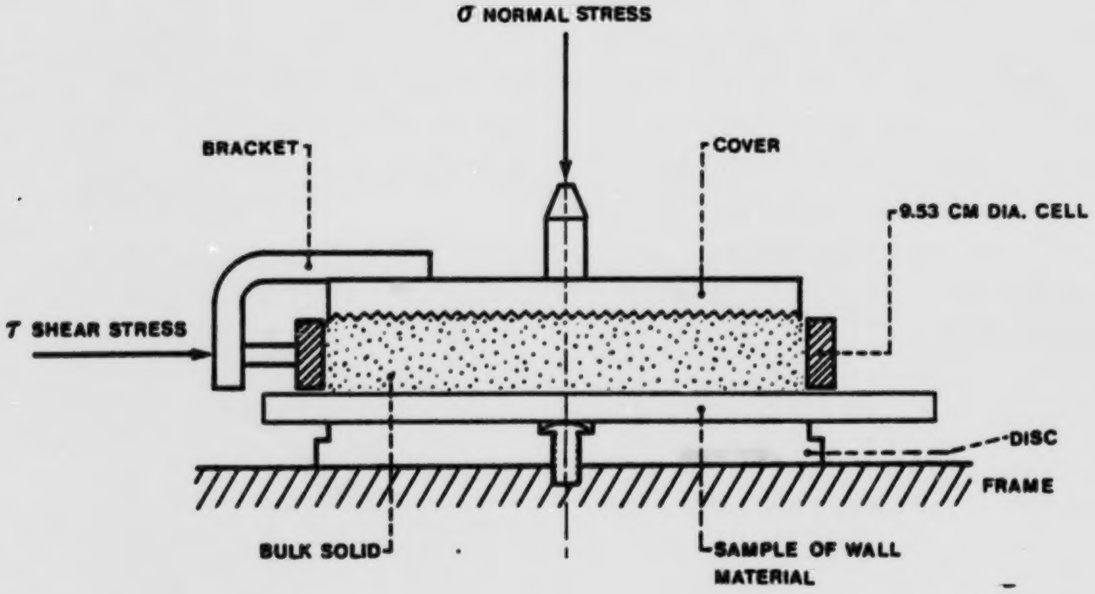
A 76 x 76 cm piece of the wall plate to be tested was placed on the table of the wall friction tester (Figure 5) and the aluminium ring placed on the plate. The ring was filled with the test sample of biomass and the cover, which fits inside the ring, placed on top. All the weight plates were placed on top of the cover. The ring was bolted in position to prevent it from turning while the cover was given a series of oscillating twists to pack the material and to obtain good contact of test material with the wall material. The bolts holding the ring down were removed and the ring lifted slightly so that its base was just clear of the wall material to ensure no friction of the ring against the wall material. The ring was linked to the transducer on the pulling mechanism by a cable. The motor was switched on and the steady state shear load was recorded. The weight plates were removed one by one and the shear loads as a result of the remaining normal loads recorded at each stage.

At the end of the test, the weight of biomass material in the cell was determined.

Testing procedure for determining wall friction for fine biomass samples on the Jenike Flow Factor tester is similar to that of the larger tester described above except that the cell is pushed via a bracket on the cover (Figure 8). The procedure is described in detail by Jenike (1).

Figure 8

CELL ARRANGEMENT FOR WALL FRICTION TESTS ON THE JENIKE FLOW FACTOR TESTER


σ NORMAL STRESS
BRACKET
COVER
9.53 CM DIA. CELL
τ SHEAR STRESS
DISC
FRAME
BULK SOLID
SAMPLE OF WALL MATERIAL

Bulk Density of Biomass

The "POURED" and "TAPPED" bulk density of each biomass sample was determined using a 16 L plastic bucket graduated at 1/2 L intervals. The test sample was poured into the bucket carefully to a known volume. The bucket was then tapped on the floor until maximum settling of material occurred; the tapped volume was recorded. The weight of the biomass sample was determined and then used to calculate poured and tapped values of bulk density.

CALIBRATIONS

Frequent calibrations of all the test equipment were done to check the accuracy of the load transducers. All the transducers performed very well with little or no drift in the readings.

Friction components in the two ring shear cells were also checked prior to each test and where necessary the shafts and the bushings were cleaned and lubricated to ensure that friction was within the acceptable range.

MOISTURE AND PARTICLE SIZE DETERMINATIONS

Moisture was determined for each sample of biomass by overnight drying at 105°C. Particle size determinations were done by screening a dried sample through a set of screens. Williamson screens with round holes were used for particle size above 5 mm. Particle size of samples with a significant portion of material of less than 5 mm in size was determined by screening with conventional screens.

VISUAL OBSERVATION OF SAMPLES

Each sample of biomass material was examined visually in order to assess characteristics that could not be determined quantitatively (eg. composition, particle shape, thickness).

RESULTS

EVALUATION

Shear Test Results

The shear test results were processed on computer to determine the flow properties using the program described in Appendix A. Typical flow properties are shown in Table 1 and a typical yield locus is illustrated graphically in Figure 9. The flow properties in Table 1 and their significance are explained below (refer to Figure 9).

The major principal consolidation stress (V1) and the unconfined yield strength (F_c) are the principal stresses corresponding to consolidation and yield strength of material; they are obtained from Mohr circle constructions on to the yield locus as shown in Figure 9.

The effective angle of friction (δ), represents the dynamic friction in the material during flow and is obtained from the slope of the line through the origin and touching the major Mohr circle.

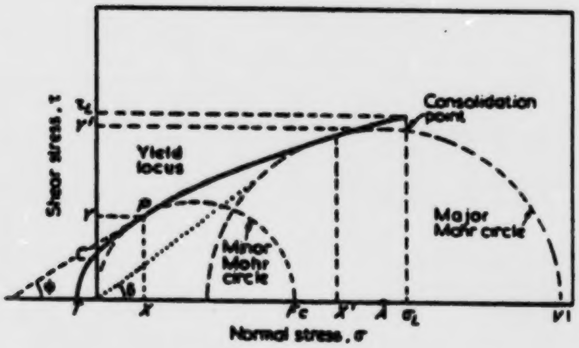
The angle of internal friction at a free surface (ϕ) represents the friction at an exposed surface of a pipe ("rat-hole") and is used in the analysis of the funnel flow bin.

The cohesion (C), and the tensile strength (T) are obtained from intersections of the yield locus with y and x axes respectively when extrapolated as shown in Figure 9.

The flow function (FF), of the material is a plot of F_c against V1 as shown in Figure 10. Superimposed on FF are hopper flow factors ff_a for mass flow, ff_d for doming * and ff_p for piping, obtained from charts derived by Jenike (1). Where the ff curve lies below the

(* doming is bridging across the width of a slot outlet whose length or diagonal has been determined to avoid piping.)

Figure 9
A TYPICAL YIELD LOCUS


Shear stress, τ
τ_L
Y'
Y
C
φ
δ
P
Yield locus
Consolidation point
Minor Mohr circle
Major Mohr circle
T
X
Fc
X'
λ
σ_L
V1
Normal stress, σ

Fc = Unconfined yield strength

V_1 = Major principal consolidating stress

δ = Effective angle of friction

ϕ = Angle of internal friction at a free arch

C = Cohesion

T = Tensile strength

TABLE 1

TYPICAL RESULTS OF FLOW PROPERTIES CALCULATED

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS (σ) G/SQ CM	SHEAR STRESS (τ) G/SQ CM	MAJ PRINC CONSOL'N STRESS (VI) G/SQ CM	UNCONFIN YIELD STRESS (Fc) G/SQ CM	FLOW FUNC (FF)	EFFECT FRIC ANGLE (δ) DEG	INTERNAL FRIC ANG AT FREE SURFACE (ψ) DEG	COHESION (C) G/SQ CM	TENSILE STRENGTH (T) G/SQ CM
24.3	31.6	68.5	33.8	2.02	58.5	54.48	4.61	1.45
45.0	49.4	112.5	45.3	2.49	54.0	54.48	6.17	1.94
60.3	58.9	137.4	45.7	3.00	50.2	54.48	6.23	1.96
85.6	70.9	176.5	46.3	3.81	45.8	54.48	6.31	1.98
115.9	87.3	225.2	50.2	4.49	43.1	54.48	6.84	2.15

SHEAR INDEX (N) = 1.53

YIELD LOCUS	PERCENT FIT
1	99.4
2	99.1
3	99.5
4	98.3
5	98.7

FF curve, stresses in the material are insufficient to cause failure and flow. Flow occurs in the region where the ff line lies above the FF curve since stresses in the arch exceed the strength of the material. The intersections of FF and ff determine the critical values of the unconfined yield strength, F_c(crit) for computing the minimum hopper outlet dimensions (B) as shown below.

$$B = \frac{m\ F_c(\text{crit})}{\gamma}$$

where m is a constant obtained from charts derived by Jenike (1)

γ is the bulk density of the material

With the majority of biomass samples, there was no intersection of FF and ff_p as shown in Figure 10, indicating that funnel flow bins are not feasible for these materials.

Wall Friction

Wall friction test results were plotted as shear stress vs normal stress and the wall friction angles were determined from the slopes of the curves. The maximum slope of the curve was used in the calculations in order to allow for some safety margin.

TEST RESULTS

Detailed results for shear tests, wall friction tests and size distributions are shown in Appendix B. A summary of the important test results including the computed values of critical bin parameters are shown in Tables 2, 3 and 4 for instantaneous consolidation. Results for time consolidation were evaluated for 20 hours and 96 hours "rest" periods to allow for comparison; these are summarized in Tables 5 and 6. Critical bin parameters of different types of mass flow bins are illustrated in Figure 11.

None of the chip samples gained in strength during time consolidation tests, and hence, results for chips are not included in Tables 5 and 6.

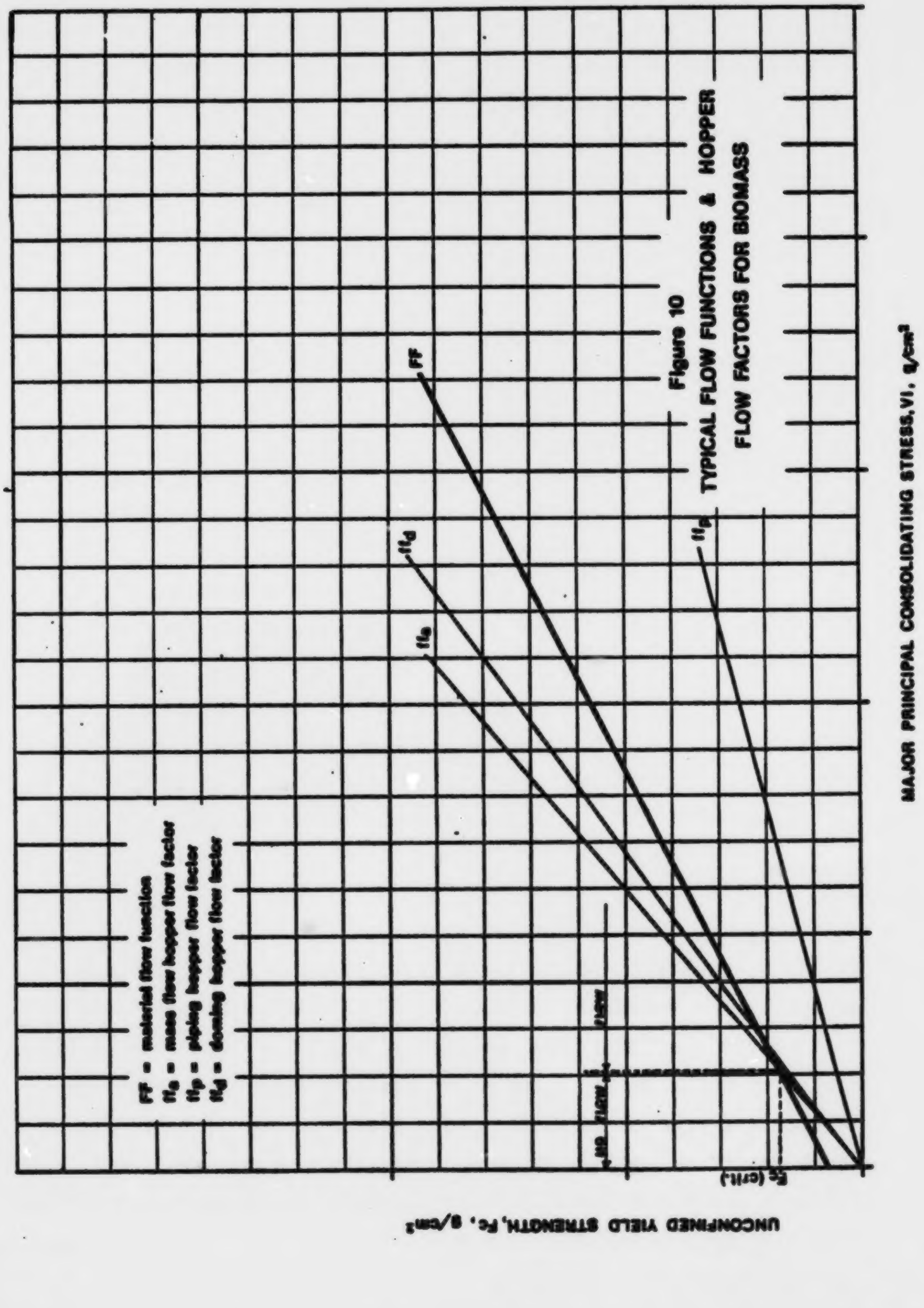
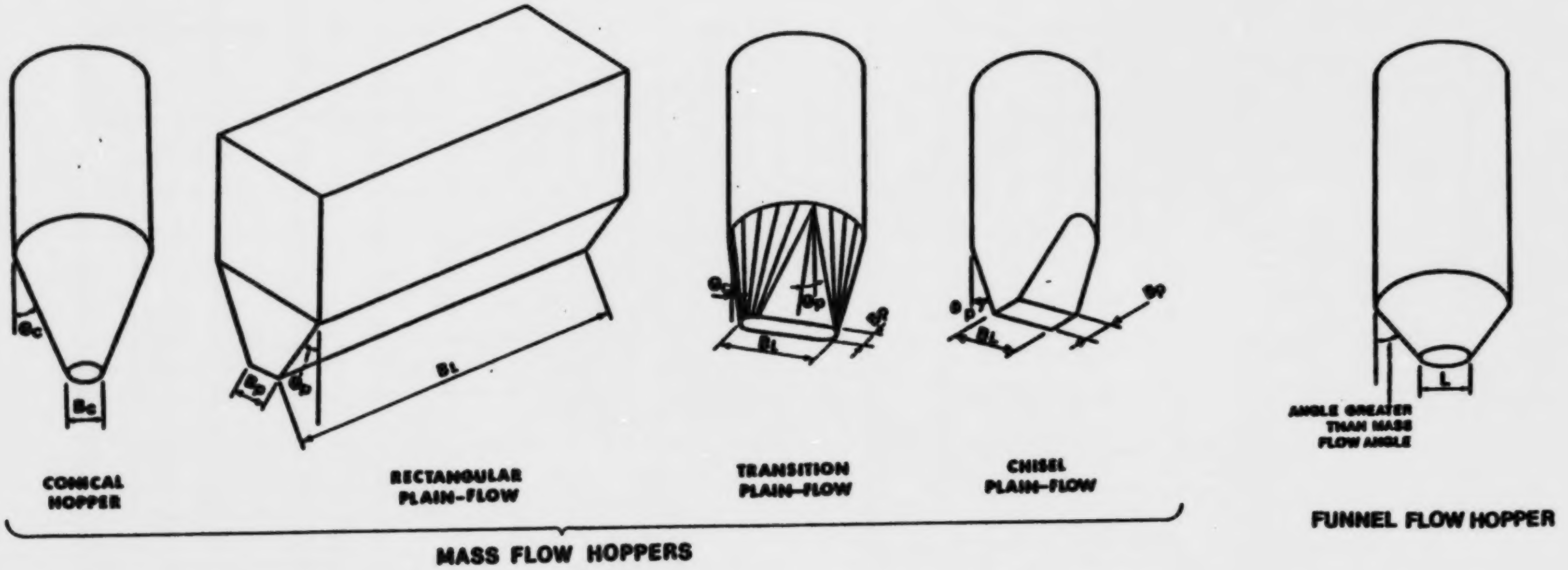


Figure 10
TYPICAL FLOW FUNCTIONS & HOPPER FLOW FACTORS FOR BIOMASS

Figure 11 CRITICAL BIN PARAMETERS


θc
Bc
CONICAL HOPPER
Bp
θp
BL
RECTANGULAR PLAIN-FLOW
θc
θp
BL
BP
TRANSITION PLAIN-FLOW
θp
BL
BP
CHISEL PLAIN-FLOW
MASS FLOW HOPPERS
L
ANGLE GREATER THAN MASS FLOW ANGLE
FUNNEL FLOW HOPPER

NOTE: L = Dia. of circular outlet or diagonal of rectangular outlet (see Tables 3 to 6)

D = Width of slot for a funnel flow bin (see Tables 3 to 6)

TABLE 2
SUMMARY RESULTS FOR HOG FUEL

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE ϕ AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (see Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (see Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm³	Conical	Plain Flow	Piping	Doming	
						ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p		B_c	B_p x B_L	L	D	
021	Hemlock Hog Fuel	41.5	6.2	0.29	0.34	34	4	16	34	4	16	16	24	37	-	-	-	28	2.30	1.16x3.48	∞	-	Sample from Vancouver sawmill; outside storage pile - several weeks storage during labour dispute. Mostly bark (fine material with some large chunks of bark) and some long, thin pieces of chips.
021A	Hemlock Hog Fuel	47.3	6.2	0.33	0.40	34	4	14	38	0	9	21	18	30	-	-	-	20	1.40	0.70x2.10	∞	-	Sample same as 021 above except wetted and left outside for 2 weeks.
022	Fir Hog Fuel	41.9	7.6	0.23	0.28	37	1	13	39	-1	10	24	16	28	-	-	-	33	3.26	1.65x4.95	∞	-	Sample from Vancouver sawmill - several weeks outside storage. Mainly fine fibrous bark.
022A	Fir Hog Fuel	47.3	7.6	0.28	0.34	33	5	16	36	1	12	20	21	32	-	-	-	40	3.29	1.65x4.95	∞	-	Same as 022 above except wetted down and left for a couple of weeks.
024	Hemlock Hog Fuel	61.9	2.5	0.37	0.49	32	6	17	33	7	16	22	18	29	-	-	-	44	2.71	1.37x4.11	∞	-	Sample from sawmill in Greater Vancouver - outside storage for over 8 weeks. Predominantly bark with a few thin chips.

TABLE 2
SUMMARY RESULTS FOR HOG FUEL (Cont'd.)

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE β AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (See Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm²	Conical	Plain Flow	Piping	Doming	
						β	θ_c	θ_p	β	θ_c	θ_p	β	θ_c	θ_p	β	θ_c	θ_p		B_c	$B_p \times B_L$	L	D	
027	Pine Spruce Hog Fuel	39.5	2.5	0.20	0.25	33	5	17	36	3	13	19	21	33	-	-	-	18	2.07	1.05x3.15	-	-	Sample from B.C. Interior pulp mill. Mostly sawdust and long, thin chips; very little bark.
030	Cedar Hog Fuel	61.8	0.8	0.24	0.35	34	4	14	36	2	12	22	18	29	-	-	-	32	3.15	1.57x4.71	-	-	Sawmill in Vancouver area; wet hog fuel from outside storage. Mostly bark in form of long stringy fibres.
031	Cedar Hog Fuel	35.6	4.2	0.16	0.21	32	6	19	33	5	16	16	24	36	-	-	-	18	2.68	1.34x4.02	-	-	Sample from same mill above;sample from "flue gas" hog fuel dryer. Mixture of fine fibrous bark and sawdust with a few chips.
031C	Cedar Hog Fuel	35.6	4.2	0.16	0.21	32	6	19	33	5	16	16	24	36	-	-	-	38	5.65	2.80x8.40	-	-	Above sample (031) frozen (-5°C).
033	Hem-Fir Hog Fuel	48.1	8.3	0.23	0.31	30	9	20	33	5	17	17	23	35	-	-	-	28	2.87	1.44x4.32	-	-	Sample from sawmill in Greater Vancouver area; outside storage. Mixture of long stringy bark, sawdust and long thin chips.

TAPLE 2
SUMMARY RESULTS FOR HOG FUEL (Cont'd.)

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE β AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (See Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm²	Conical	Plain Flow	Piping	Doming	
						β	θ_c	θ_p	β	θ_c	θ_p	β	θ_c	θ_p	β	θ_c	θ_p		B_c	$B_p \times B_L$	L	D	
034	Hem-Fir Hog Fuel	53.8	7.8	0.28	0.34	30	9	19	35	2	14	16	34	36	-	-	-	34	2.87	1.44x4.32	-	-	Sample from sawmill in Greater Vancouver area. Mixture of bark (large chunks and fibrous), shavings and sawdust.
035	Hemlock Hog Fuel	50.1	3.2	0.38	0.49	29	10	21	31	9	18	16	24	37	-	-	-	33	2.06	1.03x3.09	-	-	Outside storage; sawmill in Vancouver area. Mainly bark (fine fibrous with some large chunks); some long thin pieces of wood chips.
035C	Hemlock Hog Fuel	50.1	3.2	0.38	0.49	29	10	21	31	9	18	16	24	37	-	-	-	120	7.45	3.73x11.19	-	-	Sample (035) above frozen (-5°C).
036	Cedar Hog Fuel	58.1	2.0	0.24	0.31	32	6	17	34	3	14	17	23	35	-	-	-	25	2.46	1.23x3.69	-	-	Outside storage; sawmill in Vancouver area. Mainly fine, fibrous bark; few pieces of long thin chips.
036C	Cedar Hog Fuel	58.1	2.0	0.24	0.31	32	6	17	34	3	14	17	23	35	-	-	-	64	5.60	2.28x6.84	-	-	Sample (036) above frozen (-5°C).
040	Hem-Fir Hog Fuel	69.9	5.0	0.44	0.62	28	11	21	31	8	19	17	23	35	-	-	-	40	2.14	1.00x3.00	-	-	Outside storage; sawmill in Greater Vancouver area. Mainly fine fibrous bark with some dirt

TABLE 2
SUMMARY RESULTS FOR HOG FUEL (Cont'd.)

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE ϕ AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (See Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm³	Conical	Plain Flow	Piping	Doming	
						ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p		B_c	B_p x B_L	L	D	
040C	Hem-Fir Hog Fuel	69.9	5.0	0.44	0.62	28	11	21	31	8	19	17	23	35	-	-	-	25	1.34	0.67x2.01	-	-	Sample (040) above frozen (-5°C).
00A	Mixed Hog Fuel (mainly cedar)	58.2	3.8	0.35	-	29	10	21	34	4	15	21	19	31	39	-	8	26	1.75	0.86x2.58	8.49	1.02	Sample from sawmill in Vancouver - off conveyor from storage pile to boiler. Mostly fine fibrous bark. (Screened to minus 6.4 mm before testing).
00B	Mixed Hog Fuel (mainly cedar)	37.0	4.5	0.17	-	26	14	24	34	4	14	17	25	38	34	4	14	12	1.67	0.76x2.28	5.5	0.86	Sample from same mill as 00A above except off conveyor from"flue gas" hog fuel drier. Fine fibrous bark with some large chunks of wood (Screened to minus 6.4 mm before testing).

TABLE 3
SUMMARY RESULTS FOR WOOD CHIPS

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE β AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (See Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm²	Conical	Plain Flow	Piping	Doming	
						β	θ_c	θ_p	β	θ_c	θ_p	β	θ_c	θ_p	β	θ_c	θ_p		B_c	$B_p \times B_L$	L	D	
001	Red Cedar Chips	46.2	9.1	0.18	0.21	28	11	22	31	8	18	16	24	36	-	-	-	16	2.02	1.02x3.06	10.7	1.02	Chips fresh from wood-room, Vancouver sawmill. Very irregular thickness and shapes; mixed with fine wood particles.
002	Red Cedar Chips	52.5	7.4	0.20	0.25	30	9	19	31	7	17	15	26	37	-	-	-	27	3.19	1.53x4.59	-	-	Same as 001 above except screened to minus 1/2 inch chips.
003	Red Cedar Chips	67.9	9.1	0.30	-	-	9	19	-	4	15	-	22	34	-	-	-	17	1.30	0.65x1.95	-	-	Same as 001 above but left outside for three weeks in wet weather.
004	Red Cedar Chips	69.9	6.9	0.32	0.36	30	9	19	34	4	15	18	22	34	-	-	-	15	1.08	0.54x1.62	-	-	Same as 003 above except screened to minus 1/2 inch.
005	Hemlock Chips	46.0	9.3	0.20	0.25	29	10	20	32	6	17	17	24	35	-	-	-	14	1.65	0.80x2.40	10.34	0.86	Sample from chip silo, Vancouver Island pulp mill.
006	Hemlock Chips	48.0	7.0	-	0.42	29	10	20	32	6	17	17	24	35	-	-	-	20	1.28	0.64x1.92	-	-	Same as 005 above except screened to minus 1/2 inch. Poor quality, long, thin chips.

TABLE 3
SUMMARY RESULTS FOR WOOD CHIPS (Cont'd.)

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE ϕ AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (see Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm³	Conical	Plain Flow	Piping	Doming	
						ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p		B_c	$B_p \times B_L$	L	D	
008	Hemlock Chips	56.6	16.0	0.31	0.34	32	6	17	36	1	12	22	18	29	-	-	-	13	0.97	0.49x1.47	-	-	Fresh from woodroom of Vancouver sawmill. Irregular shape and sized chips. Some long, thin chips.
013	Fir Chips	27.2	17.5	0.18	0.19	34	4	15	34	4	15	15	27	38	-	-	-	12	1.60	0.80x2.40	-	-	Chips trucked to sawmill in Vancouver. Poor quality chips - rough sides, some small and thin.
015	Cedar Chips	51.1	14.0	0.21	0.24	33	5	15	35	2	13	18	23	34	-	-	-	56	6.27	2.81x8.43	-	-	Sample from chip silo, Vancouver Island pulp mill. Irregular shape and size (large chunks to long thin chips), rough surface.
020	Hemlock Chips	46.4	16.5	0.23	0.25	31	7	18	34	4	14	16	25	37	-	-	-	60	6.00	2.50x7.50	-	-	Sample from interior B.C. pulp mill. Rough surface, varying thickness.

TABLE 3
SUMMARY RESULTS FOR WOOD CHIPS (Cont'd.)

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE ϕ AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (See Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm²	Conical	Plain Flow	Piping	Doming	
						ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p		B_c	$B_p \times B_L$	L	D	
025	Hemlock Chips	53.3	13.7	0.28	0.31	28	11	23	30	9	20	16	27	36	-	-	-	40	3.37	1.43x4.29	-	-	Chips from Greater Vancouver area sawmill. Relatively small size chips mixed with some fibrous wood particles.
025C	Hemlock Chips	53.3	13.7	0.28	0.31	28	11	23	30	9	20	16	27	36	-	-	-	55	4.64	2.19x6.57	-	-	Sample (025) above frozen (-5°C).

TABLE 4
SUMMARY RESULTS FOR SAWDUST, PEAT & MISCELLANEOUS BIOMASS MATERIALS

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE ϕ AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (See Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm²	Conical	Plain Flow	Piping	Doming	
						ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p		B_c	$B_p \times B_L$	L	D	
010	Hemlock Sawdust	58.2	1.30	0.26	0.31	27	11	22	34	4	14	16	24	34	39	-1	9	7	0.64	0.32x0.96	17.3	0.40	Fine, fibrous sample fresh from woodroom - Vancouver sawmill.
012	Cypress Sawdust	49.6	1.78	0.29	0.33	25	15	26	31	8	18	16	26	38	35	3	12	6	0.37	0.19x0.67	-	-	Sample from storage bin - Vancouver sawmill. Some thick pieces mixed with mainly fibrous material.
014	Cedar Sawdust	66.3	1.64	0.30	0.37	27	13	24	33	5	15	13	30	42	37	0	12	6	0.50	0.25x0.75	6.5	0.27	Sample from outside storage pile - Vancouver sawmill. Mixture of fine and coarse fibrous particles.
018	Fir Sander Dust	4.3	0.20	0.09	0.11	18	22	34	34	4	13	17	23	36	-	-	-	7	1.84	0.92x2.76	67.0	1.02	Sample from Greater Vancouver plywood plant. Obtained from pneumatic conveyor feeding boiler.
019	Cedar Dust	11.0	0.01	0.10	0.13	16	26	38	33	5	16	18	23	35	36	1	11	7	1.67	0.84x2.52	18.2	0.81	Sample from Vancouver plant manufacturing cedar boards from kiln dried lumber. Material stored outside under cover for several weeks.

TABLE 4
SUMMARY RESULTS FOR SAWDUST, PEAT & MISCELLANEOUS BIOMASS MATERIALS (Cont'd.)

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE ϕ AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (See Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm²	Conical	Plain Flow	Piping	Doming	
						ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p	ϕ	θ_c	θ_p		B_c	$B_p \times B_L$	L	D	
026	Hemlock Sawdust	57.5	1.60	0.26	-	23	17	28	33	5	16	16	25	37	35	2	13	18	1.64	0.82x2.46	-	-	Sample from Greater Vancouver sawmill; outside storage for several weeks.
028	Hem-Fir Sawdust	31.3	2.70	0.20	-	28	11	22	34	4	16	16	25	37	38	-	8	8	0.96	0.47x1.41	-	-	Interior B.C. pulp mill.
029	Cedar Sawdust	68.1	2.00	0.31	-	27	13	23	32	6	16	20	21	32	39	-	6	7	0.54	0.27x0.81	2.94	0.26	Sample from outside storage pile, Vancouver sawmill.
023	Grain dust	10.6	-	0.36	0.40	12	32	44	25	16	25	13	30	43	32	4	15	9	0.58	0.30x0.90	2.16	0.29	Sample from grain terminal, Vancouver.
023A	Pelletized Grain Dust	-	-	0.56	0.68		32	44		24	34		31	42	-	-	-	18	0.83	0.41x1.23	1.88	0.40	Sample from grain terminal, Vancouver.
037	Peat	82.6	0.98	0.31	0.40	50	-	-	50	-	-	40	-	-	34	4	15	12	0.92	0.46x1.38	6.25	0.60	Sample from Richmond, B.C. Mechanically dewatered but not dried.
038	Peat	57.5	0.30	0.17	0.21	47	-	-	41	-	-	36	2	12	36	1	11	6	0.60	0.30x0.90	3.32	0.64	Sample from Richmond, B.C. Mechanically dewatered and dried.

TABLE 4
SUMMARY RESULTS FOR SAWDUST, PEAT & MISCELLANEOUS BIOMASS MATERIALS (Cont'd.)

SAMPLE NO.	MATERIAL &SPECIES	% MOISTURE	MEAN PARTICLE SIZE mm	BULK DENSITY g/cm³		WALL FRICTION ANGLE β AND MAX. MASS FLOW HOPPER ANGLES θ_c & θ_p (See Figure 11)												CRITICAL UNCONFINED YIELD STRENGTH (Fc_{crit}) & MIN. OUTLET DIMENSIONS (m) FOR INSTANTANEOUS CONSOLIDATION (See Figure 11)					COMMENTS
				Poured	Tapped	Stainless Steel			Mild Steel			Ultra High Density Polymer			Concrete			Mass Flow Bin			Funnel Flow Bin		
																		Fc_{crit} g/cm²	Conical	Plain Flow	Piping	Doming	
						β	θ_c	θ_p	β	θ_c	θ_p	β	θ_c	θ_p	β	θ_c	θ_p		B_c	$B_p \times B_L$	L	D	
039	Peat	57.5	0.56	0.17	0.22	56	-	-	42	-	-	46	-	-	35	2	12	3.0	0.43	0.22x0.66	2.95	0.24	Manitoba peat. Mechanically dewatered and dried.
009	Hemlock	39.9	4.7	0.12	0.16	33	6	16	38	-	10	19	21	33	-	-	-	25	4.80	2.40x7.20	-	-	Sample from Vancouver sawmill - outside storage pile.

TABLE 5

SUMMARY OF RESULTS FOR TIME CONSOLIDATION TESTS ON HOG FUEL

Sample No.	Material and Species	% Moisture	Mean Particle Size mm	Critical Outlet Dimensions For Mass Flow Bins (meter) (See Figure 11)				Increase in Min. Outlet Dimension Due to Time Consolidation For 96 Hours
				Length of Storage at Rest				
				20 Hours		96 Hours		
				Conical Hopper B_c	Plain-Flow Hopper $B_p \times B_L$	Conical Hopper B_c	Plain-Flow Hopper $B_p \times B_L$	% of instantaneous dimensions see Tables 2-4
021	Hemlock Hog Fuel	41.5	6.2	3.61	1.61x4.83	5.50	2.48x7.44	139
021A	Hemlock Hog Fuel	47.3	6.2	2.09	0.98x2.94	2.09	0.98x2.94	82
022	Fir Hog Fuel	41.9	7.6	4.93	2.46x7.38	4.93	2.46x7.38	51
022A	Fir Hog Fuel	47.3	7.6	4.60	1.97x5.91	6.40	2.71x8.13	95
024	Hemlock Hog Fuel	61.9	2.5	4.93	2.46x7.38	9.74	4.87x14.61	259
027	Pine-Spruce Hog Fuel	39.5	2.5	4.14	1.76x5.28	5.75	2.46x7.38	178
030	Cedar Hog Fuel	61.8	0.8	6.48	2.60x7.80	6.49	2.60x7.80	106
031	Cedar Hog Fuel	35.6	4.2	6.54	1.14x3.42	6.54	1.14x3.42	225
033	Hem-Fir Hog Fuel	48.1	8.3	6.16	3.08x9.24	6.16	3.08x9.24	115
034	Hem-Fir Hog Fuel	53.8	7.8	3.88	1.94x5.82	5.73	2.86x8.58	100
035	Hemlock Hog Fuel	50.1	3.2	3.23	1.62x4.86	3.23	1.62x4.86	58
036	Cedar Hog Fuel	58.1	2.0	2.74	1.37x4.11	3.72	1.86x5.58	52
040	Hem-Fir Hog Fuel	69.9	5.0	3.36	1.40x4.20	5.71	2.30x6.90	167

TABLE 6

SUMMARY OF RESULTS FOR TIME CONSOLIDATION TESTS ON SAWDUST AND PEAT

Sample No.	Material and Species	% Moisture	Mean Particle Size mm	Critical Outlet Dimensions For Mass Flow Bins (meter) (See Figure 11)				Increase in Min. Outlet Dimension Due to Time Consolidation For 96 Hours % of instantaneous dimensions see Tables 2-4
				Length of Storage at Rest				
				20 Hours		96 Hours		
				Conical Hopper B_c	Plain-Flow Hopper B_p x B_L	Conical Hopper B_c	Plain-Flow Hopper B_p x B_L	
010	Hemlock Sawdust	58.2	1.30	0.64	0.32 x 0.96	0.64	0.32 x 0.96	0
012	Cypress Sawdust	49.6	1.78	1.07	0.53 x 1.59	1.07	0.53 x 1.59	189
014	Cedar Sawdust	66.3	1.64	0.98	0.49 x 1.47	0.98	0.49 x 1.47	96
018	Fir Sander Dust	4.3	0.18	1.84	0.92 x 2.76	1.84	0.92 x 2.76	0
019	Cedar Dust	11.0	0.01	2.62	1.19 x 3.57	2.62	1.19 x 3.57	57
026	Hemlock Sawdust	57.5	1.60	1.82	1.36 x 4.08	1.82	1.36 x 4.08	11
028	Hem-Fir Sawdust	31.3	2.70	1.78	0.77 x 2.31	2.31	1.03 x 3.09	143
029	Cedar Sawdust	68.1	2.00	0.54	0.27 x 0.81	0.54	0.27 x 0.81	0
037	Peat	82.6	0.98	3.48	1.59 x 4.78	3.48	1.59 x 4.76	278
038	Peat	57.5	0.30	2.40	1.09 x 3.27	2.40	1.09 x 3.27	458
039	Peat	57.5	0.56	2.05	0.96 x 2.88	2.05	0.96 x 2.88	242

DISCUSSION

HOPPER TYPE

Most storage bins require hoppers (converging sections) to enable the bin to taper to an outlet size that is small enough to discharge to a feeder. As explained earlier in the Introduction, two types of hopper configurations are possible for most bulk materials - mass flow and funnel flow hoppers. For the majority of biomass materials tested, funnel flow bins are either impossible or require impractically large openings. Hence, mass flow hopper design is essential. Mass flow hoppers are characterized by smooth, steep walls, the wall angle being dependent on the friction of the biomass material against the appropriate wall material.

Two basic shapes of mass flow hoppers are possible - conical and plain flow hoppers as shown in Figure 11. The wall angle to the vertical of a plain flow hopper is 10 to 12 degrees higher than a conical hopper and hence, a plain flow bin is more efficient in terms of space occupied when a given quantity of material is to be stored. The disadvantage is that the material has to be withdrawn out of a long, narrow slot opening. The need to draw material out uniformly from the whole outlet makes feeder design somewhat tricky for a plain-flow outlet.

BIN WALL MATERIALS OR LINERS

Most biomass samples tested had very high wall friction against common bin wall constructional materials - concrete, mild steel and stainless steel. Conical hoppers made out of these materials would have to be impractically steep for most cases. Since plain-flow hoppers require slopes that are 10 to 12 degrees less steep, stainless steel and in some cases mild steel plain-flow hoppers can be used for the biomass materials tested. In practice, the use of cylindrical bins with conical outlets is more prevalent, especially for large capacity silos. Therefore, the need for less conventional bin wall material or a liner with lower frictional characteristics against biomass becomes apparent.

Tests done with two different samples of ultra high molecular polymer showed excellent frictional characteristics for this material against biomass, hence, enabling use of very practical hopper wall angles, even for conical hoppers. Only two wall friction tests were done with glass but both indicated low wall friction angles against biomass, making it suitable as a bin liner.

Tests on peat samples showed that none of the wall materials tested, including UHMP and glass, had a low enough wall friction to allow mass flow to develop. Hence, while a mass flow bin for peat would have a very practical configuration because of the small outlet sizes necessary, a suitable bin wall material or liner has yet to be found to permit mass flow hopper design.

MINIMUM OUTLET DIMENSIONS

Minimum outlet dimensions for mass flow hoppers have been computed for instantaneous and time consolidation conditions. Instantaneous consolidation represents conditions of continuous discharge of the bin without "rest" periods. Outlets computed for time consolidation allows for gain in strength for the specified "rest" periods.

The minimum outlet dimensions are influenced by two main factors:

- the critical unconfined yield strength which is a measure of the cohesive strength of the material,

- the bulk density which is responsible for the gravitational forces assisting the material to flow. The larger the value of the bulk density the smaller the outlet size necessary to avoid bridging.

In comparison with other common bulk materials, the critical values of the unconfined yield strengths for most biomass materials tested are not considered to be high under instantaneous consolidation. The bulk density of biomass is however, several times lower, and hence, it is necessary to have outlets that are considerably larger than those used for other bulk materials. Nevertheless, the minimum outlet sizes determined for instantaneous consolidation for the majority of biomass samples tested were less than 3.5 metres (conical hopper), which is well within the range the forest industry is used to and are considered to be practical in the industry.

Hog fuel was found to have the highest strength, followed by wood chips and then sawdust and peat. There was considerable variation in the minimum outlet sizes determined, reflecting the effects of different species, composition, particle size distribution, moisture and other physical characteristics. The large number of variables make it difficult to differentiate the effect of individual variables conclusively; some tendencies were, however, evident.

Increased moisture increased the bulk density of biomass significantly while the increase in cohesion was proportionately smaller; for some samples, there was an actual drop in the cohesion with an increase in moisture. The net effect is that drier biomass will require larger bin outlets.

Biomass flowability appeared to be less sensitive to mean particle size than to size distribution. The presence of fines with coarse particles appeared to result in poorer flow properties.

Minimum mass flow outlet sizes (conical hoppers *) for hog fuel at instantaneous consolidation ranged from 1.4 to 3.3 metres when not frozen. Of the 15 samples tested, only 3 required outlets greater than 3 metres. Hence, a 3 metre outlet will be sufficient for the majority of hog fuel provided that the material is not stored at "rest".

* Note: the equivalent minimum slotted outlets are:
width = approximately half the diameter of conical outlet
length = 3 times the width

Minimum conical hopper outlets for chips ranged from 1 to 6 meters; the majority of wood chip samples, however, required outlets of less than 2 meters (conical mass flow hopper). Two samples of chips tested required outlets in excess of 6 meters - both samples were fairly dry and had rough surfaces formed from fracturing, rather than from the cutting action of a sharp chipper. Hence, for the majority of chips, a 2 meter mass flow conical hopper outlet is considered adequate.

The majority of sawdust samples under instantaneous consolidation required outlets under 1 meter (conical mass flow hopper) except when very dry.

Peat was found to have very low strength permitting quite small outlets (less than 1 meter) for mass flow hoppers - under instantaneous consolidation. However, since mass flow hoppers are difficult to design for peat because of its very high wall friction against all of the wall materials tested, funnel flow outlet dimensions will be of special interest. Dry peat required minimum outlets of about 3 meters for funnel flow hoppers under instantaneous consolidation - this is considerably more practical than funnel flow bins for hog fuel or wood chips.

TIME CONSOLIDATION

With the exception of wood chips, all of the biomass samples tested gained in strength during time consolidation. In the case of hog fuel, the increase in strength was considerable, in many cases requiring very large openings if discharge were to rely on gravity alone. About half of the samples tested gained maximum strength in the first 20 hours of time consolidation; the remaining samples continued gaining in strength depending on the length of storage at rest. In most cases impractically large openings would be necessary to allow for storage at rest. However, if external devices can be used to initiate flow, opening sizes determined under "instantaneous" consolidation will be sufficient to maintain flow from the bin.

Another solution is to continue discharging the bin at a very slow rate and recycle the material into the bin from the top during "rest" periods.

None of the chip samples tested gained in strength during time consolidation and this is the reason why fewer problems exist with chip bins as compared to bins for hog fuel.

All but one sample of sawdust gained maximum strength during overnight consolidation (20 hours). Hence, an outlet that is sized to allow for 20 hours of time consolidation will likely permit flow even after considerably longer periods of storage at rest. The gain in strength varied considerably between samples. The outlet sizes required to allow for the increased strength were less than 2 metres (conical hopper) for all but one of the samples tested.

The 3 peat samples tested gained maximum strength during the first 20 hours of time consolidation; the increase in strength was however, the highest of all biomass samples tested. Nevertheless, for dry peat, minimum outlet dimensions for mass flow hoppers were about 2.5 meters for the two samples tested. For the one sample of wet peat, the minimum outlet was 3.5 meters. The piping dimensions for time consolidation for peat were too large to be of practical value. Hence, in the absence of a suitable bin wall material for mass flow hopper design, peat must not be left in storage at rest if flow problems are to be avoided.

FREEZING CONDITIONS

Tests at below freezing temperatures were somewhat more exacting than is likely to be encountered in the field - as explained earlier in the report. The test samples of hog fuel were pre-frozen in plastic bags prior to their testing in the ring shear cell. The excellent insulation properties of biomass will prevent freezing up of the entire contents of a storage bin except under severe conditions. It is more likely that a layer of biomass along the wall will freeze up, the centre core remaining unfrozen.

Results of 3 of the 4 tests on hog fuel show that minimum mass flow hopper outlets will be too large to be practical. For the fourth sample, the minimum outlet for a mass flow conical hopper was less than 1.5 m. Surprisingly, this result was obtained at high moisture content - the sample was found to have improved flowability at below freezing compared to its flowability at ambient temperature.

Only one test was done on frozen wood chips. Results showed deterioration in flow characteristics to the point where too large an outlet would be necessary under instantaneous conditions.

Time consolidation tests on frozen samples showed very severe deterioration in the flowability of all of the samples tested; mass flow outlets that would be necessary are too large to be of practical significance.

If, as anticipated, freezing of the layer of biomass along the bin wall takes place instead of the entire contents of the bin, the result will be funnelling of material over itself leading to non-mass flow. Hence, stoppages in flow can be expected from piping ("rat-holing").

Based on the tests performed, flow problems can be expected regardless of the extent of freezing and it is unlikely that a bin can be designed to discharge frozen material under gravity alone. Some means of preventing freeze-ups (insulation of bin and/or external heating) or mechanical discharge will be necessary to avoid flow problems under freezing conditions.

BULK DENSITY OF BIOMASS

As explained earlier, the bulk density of biomass affects the gravitational force in a bin necessary to prevent formation of a stable arch. The bulk densities used in computing the minimum outlet dimensions are based on the "poured" density, as is customary in these calculations, in order to allow for a safety margin in the design.

The actual bulk densities of biomass at the outlet may be considerably higher as biomass can compact a lot more than most bulk materials. Hence, the safety margin in the computed outlets may be more than is necessary or desirable.

RECOMMENDATIONS

The recommendations on minimum bin outlet sizes given below are based on results of tests carried out on hog fuel, wood chips, sawdust, shavings and peat. The values are intended as guidelines for the design of biomass storage bins and silos. However, because of the high variability of biomass, tests are recommended on the actual biomass samples under consideration prior to selection of minimum bin outlet dimensions.

1. Mass flow hopper design is recommended for all biomass materials with the exception of peat for which a suitable bin wall material or liner permitting practical hopper angles has not been found. Funnel flow hoppers will lead to piping and hence, stoppages in flow.

2. Concrete is unacceptable as a mass flow hopper wall material for biomass because of its very high wall friction. Both mild steel and stainless steel will require impractically steep walls for conical hoppers and, hence, are not recommended for such hoppers. Since plain-flow hoppers (slotted outlets) generally require wall slopes that are 10 to 12 degrees less steep, such hoppers in mild and stainless steel, although steep, will be marginally acceptable and may be used where conditions permit.

   Since the surface of mild steel is prone to corrosion, material must not be stored at rest in a bin with a mild steel hopper as the increase in friction due to surface corrosion will be sufficient to prevent mass flow from developing.

   Ultra high molecular polymer (UHMP) liner will enable very practical hopper wall angles, especially for plain-flow hoppers. The hopper wall angle to the vertical will be at least 30° (60° included angle) for a plain-flow hopper; and since many existing bins experiencing flow problems will have this minimum slope, UHMP will be particularly useful for retrofitting of such bins.

Sufficient service data is not yet available on the use of UHMP as a bin liner although the material has been used in the forest products industry for lining bottoms of conveyors and ducts with good results in terms of wear and power reduction. Installation to plain-flow hoppers with flat sides will likely be considerably easier compared to hoppers with curved surfaces where it will be necessary to either bend the sheets or install the material in the form of small "tiles" or strips. Hence, the design of rectangular mass flow bins with flat sides is especially recommended because of the added advantage of lower wall slopes.

4. Special attention must be paid to fastening of bin liners to walls to ensure that fasteners do not obstruct mass flow.

5. Based on a limited number of tests, glass is also recommended as a bin wall material. While the wall friction of glass against biomass is not as low as UHMP, it is nevertheless in the acceptable range and will permit practical hopper designs. Glass lined bins are available with glass fused to steel, thus, avoiding any fastening problems as in the case of UHMP.

6. Minimum mass flow outlets of approximately 3 m for conical hoppers and 1.5 m x 4.5 m for slotted outlets are recommended for hog fuel under instantaneous consolidation conditions, ie., material is discharged continuously without "rest" periods. Where storage at rest is necessary, external flow activating devices are recommended to initiate flow; alternatively, the contents of the bin can be discharged continuously at a slow rate and recycled into the bin.

7. Minimum mass flow outlets of approximately 2 m for conical hoppers and 1 m x 3 m for slotted outlets are recommended for wood chips. Wood chips will not gain strength during time consolidation (unless excessive quantities of fines are present), permitting flow from outlets sized as above following periods of storage at rest.

8. Sawdust will require minimum mass flow outlets of approximately 1 m for conical hoppers and 0.5 m x 1.5 m for slotted outlets under "instantaneous" consolidation conditions, ie. continuous discharge without "rest" periods. Where the outlet has to be sized to allow flow following storage at rest, minimum mass flow outlets of approximately 2 m are recommended for conical hoppers and 1 m x 3 m for a slotted outlet. Sawdust will gain its maximum strength during the first 20 hours of time consolidation and hence a larger outlet will not be necessary for longer time consolidation periods.

   Note: The minimum bin outlet dimensions recommended above are for materials with moderate to high moisture contents (25% to 70%). For very low moisture contents (less than 10%) and hence, very low bulk densities, the outlet sizes required will be considerably larger and gravity discharge will not be feasible on its own. In such cases some form of flow assistance is recommended.

9. Based on tests done on 3 samples of peat, mass flow bin design is impractical with any of the bin wall materials tested (including UHMP and glass). A search for a suitable liner or paint is recommended in order to reduce wall friction to an acceptable level and permit mass flow bin design.

Funnel flow bin design is however practical for dry peat (less than 60% moisture) under "instantaneous" consolidation only (continuous bin discharge without rest periods). Peat gains rapidly in strength when stored at rest in a bin and mechanical discharge is recommended in this case.

One test on wet peat (mechanically dewatered but not dried) indicated that gravity discharge alone is not practical even under "instantaneous" conditions. Mechanical discharge is recommended in this case.

PRECAUTIONS FOR BIN-FEEDER DESIGN

In order to attain maximum design capabilites of a mass flow bin, attention must be given to a number of practical details. Many of these details are applications of common sense and are well documented in several publications (1,3,4). However, they are frequently overlooked and lead to flow problems, and sometimes can negate the effect of mass flow bin design. For the benefit of the designer, the essential precautions are outlined below:

1. Fully Active Bin Outlet

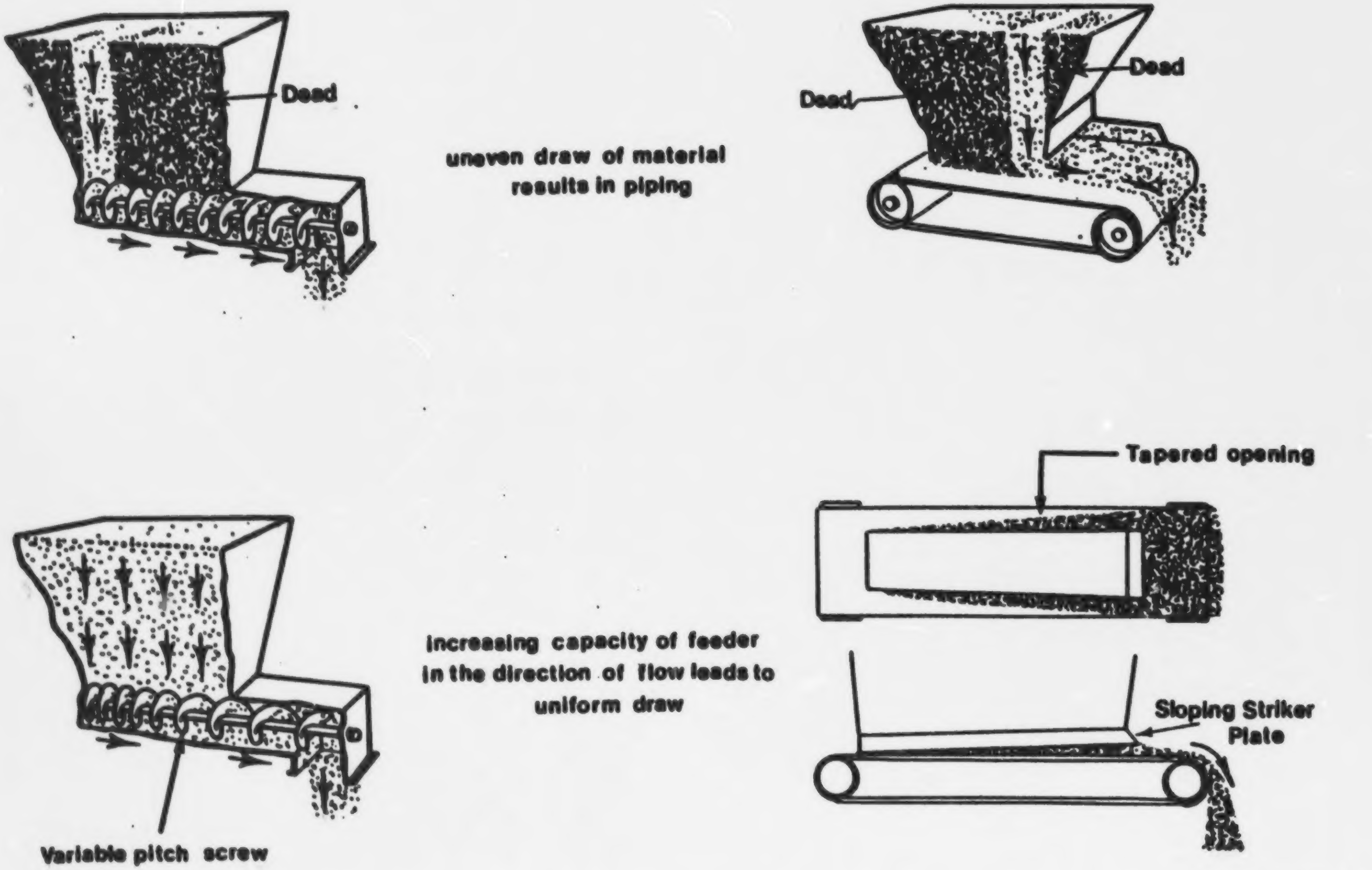
Where a feeder is used to discharge the contents of a mass flow bin, it is essential that the feeder be designed to draw uniformly from the whole bin outlet. This is especially critical for a long slotted outlet where piping can occur with non-uniform draw of material as shown in Figure 12. The problem can be corrected by increasing the capacity of the feeder in the direction of flow. For a screw feeder, this can be achieved by increasing the pitch or diameter of the screws. A tapered opening will also correct the problem for a belt feeder.

2. Eliminate Protruding Edges

Any part of the bin or accessories protruding into a hopper will interfere with flow and can prevent mass flow from developing. Common problems are fasteners for liners as shown in Figure 13. Fasteners should be recessed into the liner and any gap filled with material of equivalent or lower friction.

Any joins in walls or liners must be butt or overlap "shingle style" as shown in Figure 14.

Figure 12 FEEDER DESIGN FOR A FULLY ACTIVE OUTLET

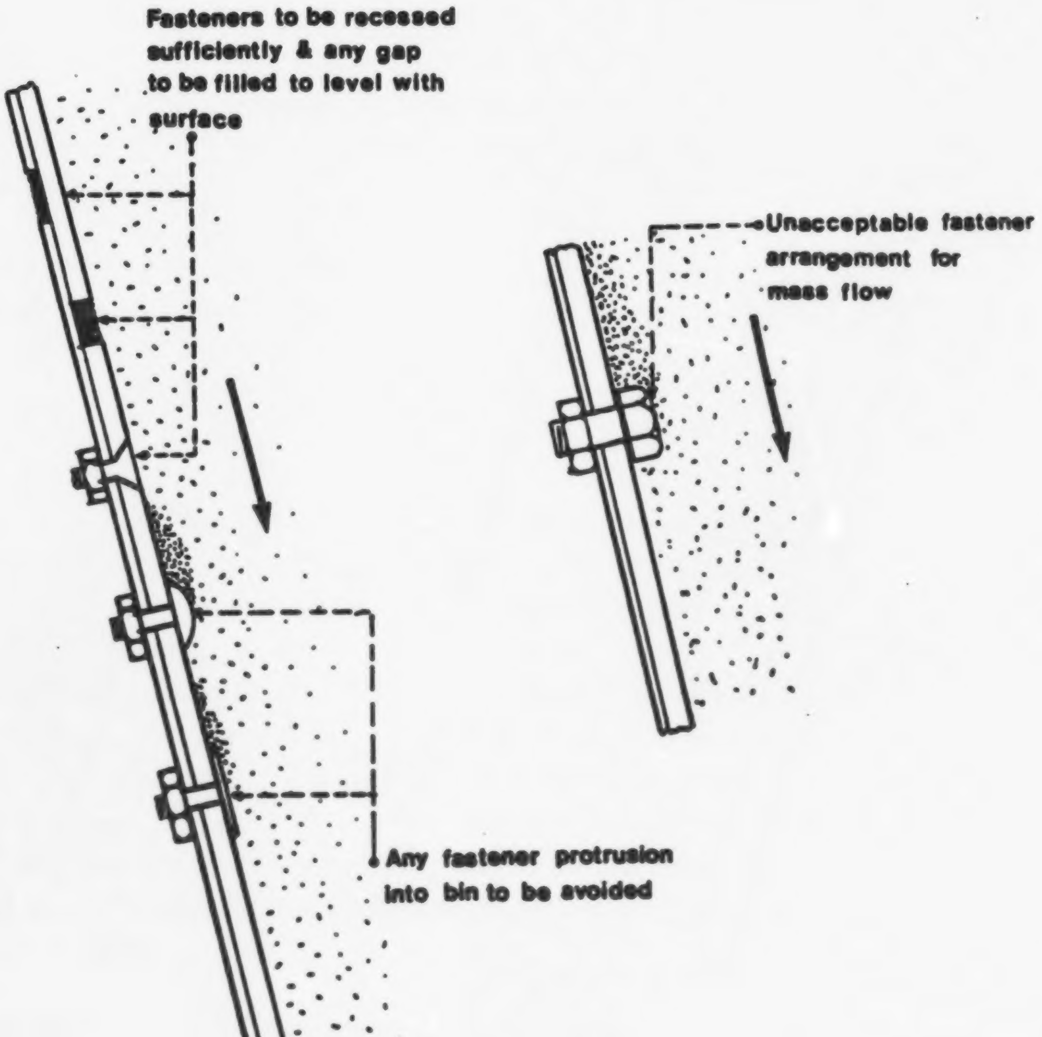

Dead
Dead
Dead
Tapered opening
Sloping Striker Plate
Variable pitch screw

uneven draw of material results in piping

increasing capacity of feeder in the direction of flow leads to uniform draw

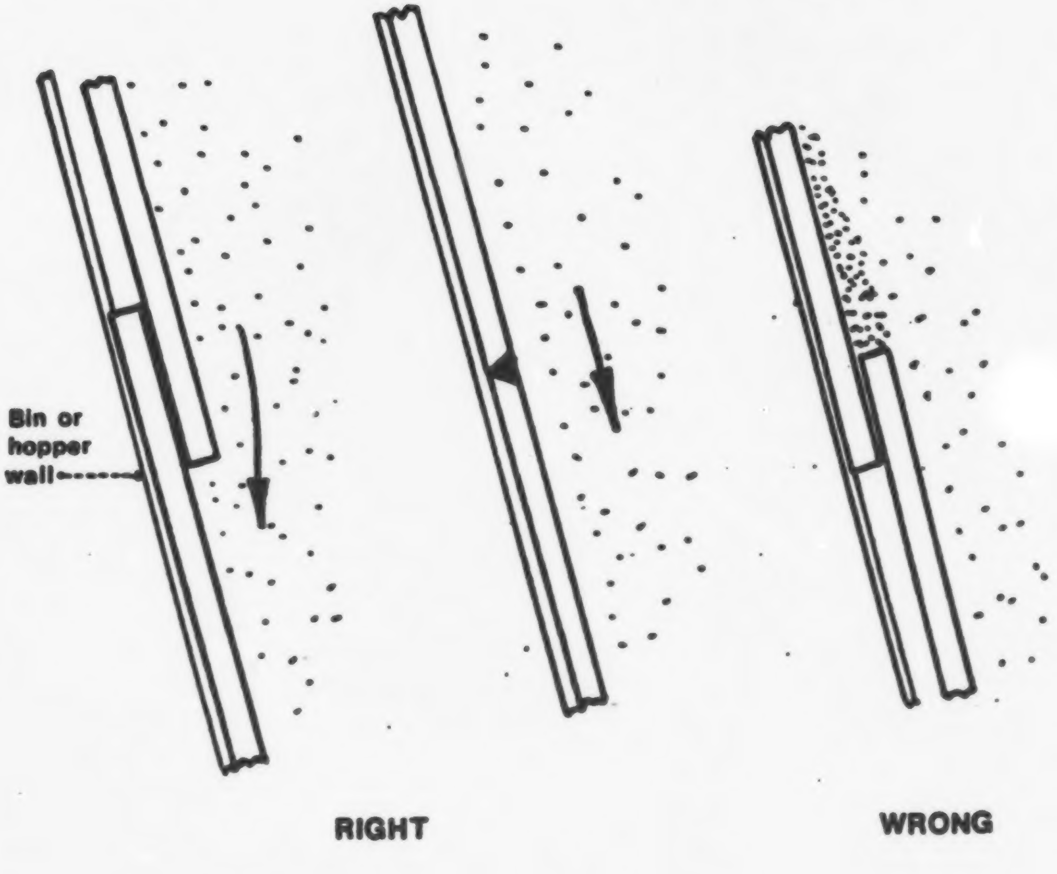
From Arnold et al. (4)

Figure 13 FASTENER ARRANGEMENT


Fasteners to be recessed sufficiently & any gap to be filled to level with surface
Any fastener protrusion into bin to be avoided
Unacceptable fastener arrangement for mass flow

From Doeksen (3)

Figure 14 JOINS IN WALLS OR LINERS


Bin or
hopper
wall

RIGHT

WRONG

From Deeksen (3).

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STAFF

This project was carried out in the Chemical Technology Division under the supervision of Mr. Nazmir Bundalli, P.Eng. Mr. Roy Farley, a consultant from the U.K., provided general guidance during the design of special flow testing equipment as well as in the development of testing procedures and data interpretation. Mr. Bobbie Rattayats and Mr. Duncan Morgan assisted in the detailed design of the test equipment. The equipment was constructed and assembled at B.C. Research workshops by Mr. Gordon Grady. Testwork was carried out by Mr. Omar Martinez and Mr. Laurie Hunt. The evaluation and interpretation of results and preparation of this final report was done by Mr. Bundalli.

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Crown Zellerbach, Coast Wood Products Div., New Westminster
Fisons Western Peat, Delta
Intercontinental Pulp, Prince George
MacMillan Bloedel, Harmac Div., Nanaimo
MacMillan Bloedel, Canadian White Pine Div., Vancouver
Northwood Pulp, Prince George
Richmond Plywood, Richmond
Terminal Sawmills, Vancouver
United Grain Growers, Vancouver
West Coast Cellufibre, Vancouver
Weyerhaeuser Canada, Kamloops
Whonnock Lumber Industries, New Westminster.

DEFINITIONS

Bin	Storage container for bulk material with outlet(s) for withdrawal. A bin is considerably smaller in size compared to a silo.
Bridging	Stoppage in flow due to formation of a stable arch or dome of material across outlet.
Cohesion	The resistance of a bulk material to shear, and hence, flow.
Conical Hopper	Hopper off a cylindrical bin with a circular outlet.
Consolidation	Preparation stage of a sample of bulk material in a shear cell prior to determination of its yield strength; involves shearing of loosely packed material until it gains in strength to reach a steady state shear stress.
Doming	Bridging across the width of a slot outlet sized to prevent piping.
Effective Angle of Friction	Dynamic friction within material; obtained from the slope of the yield locus at the point where the major Mohr circle touches it.
Flow Factor	Ratio defining flow properties of a hopper; constant for a given hopper.
Flow Function	Ratio defining flow properties of a bulk material (major principal consolidating stress/unconfined yield strength).

Funnel Flow	Flow pattern in which solids flow in a channel formed within stagnant material; occurs as a result of hopper walls not being steep and/or smooth enough.
Hopper	Converging part of a bin or silo where the width or diameter tapers to a size suitable for discharging to a feeder.
Internal Angle of Friction	Static angle of friction within a bulk solid; obtained from the slope of the yield locus at the point where the minor Mohr circle touches it.
Instantaneous Consolidation	Represents conditions of continuous flow without rest periods.
Major Principal Consolidating Stress	Principal stress corresponding to consolidation of a bulk material.
Mass Flow	Flow pattern in which material slides over the hopper walls as a solid mass with little relative movement between the particles; results in "first-in-first-out" flow.
Piping	Formation of a stable vertical pipe ("rat-hole") resulting in stoppage of flow.
Plain-flow Hopper	Hopper which is not conical in shape and has a slot (long, narrow) outlet.
Silo	Continer for bulk material with outlet(s) for withdrawal. A silo is considerably larger in size compared to a bin.

Time Consolidation	Represents conditions of storage at rest in a bin when no material is withdrawn.
Unconfined Yield Strength	Principal stress corresponding to yield or failure of a bulk material.
Wall Friction	Friction of a bulk material against bin wall material.
Yield Strength	Shear strength a bulk material needs to overcome in order to fail and hence, flow.
Yield Locus	Plot of yield strength vs. normal stress for a given consolidation pressure.

ABSTRACT OF THE ABSTRACT

Extensive flowability tests were done on biomass materials. Critical bin design parameters to prevent flow problems were evaluated.

BIN AND SILO DESIGN FOR BIOMASS MATERIALS

APPENDICES A AND B

ENFOR PROJECT C-130

DSS Contract No: 41SS.KL 229-0-4120

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Project No: 207-596

APPENDIX A

EVALUATION OF RESULTS

COMPUTER PROGRAM

Shear test data were processed on computer to obtain flow properties which in turn were used to compute the critical bin parameters to avoid bridging and piping. The computer program (A1) was obtained from Warren Spring Laboratory in the U.K. and translated into BASIC from ALGOL. The program and the theory behind the calculation are briefly described below.

The most critical part of the program is to fit the shear test data to the Warren Spring yield locus equation (A2):

$$(\tau/C)^n = \sigma/T + 1 \qquad \text{. . (A1)}$$

where τ = shear stress

σ = normal stress

n = shear index

C = cohesion

T = tensile strength

τ and σ are obtained from experimental data; n and the ratio C/T (=K) are constants for a given material (A3, A4). C and T vary for individual yield loci.

First, all the yield loci are reduced to a single yield locus called the SPECIFIC yield locus (A4) by dividing all the normal and shear stresses by their respective consolidating normal stresses. The reduced yield locus equation is then fitted to these points:

$$\tau = C_S(\sigma/T_S + 1)^{1/n} \qquad \text{. . (A2)}$$

where C_S and T_S are specific cohesion and specific tension respectively.

The best values of n and K (= C_s/T_s) are obtained by minimizing the following regression function:

$$S = \sum_{i=1}^{N} \{\tau_i - \frac{C_s(\sigma i/T_s + 1)^{1/n}}{T_s}\}^2 \qquad . . (A3)$$

where N is the total number of points in all the yield loci.

The parameters n and K are constant and independent of consolidation conditions. Following their determination from the reduced yield locus, two other parameters, C and T, can be determined individually for each yield locus, described by the equation:

$$\tau = KT (1 + \sigma/T)^{1/n} \qquad . . (A4)$$

T and, hence, C are evaluated by minimizing the regression function

$$S = \sum \{\tau_i - KT (1 + \sigma_i/T)^{1/n}\}^2 \qquad . . (A5)$$

The percentage fit of the experimental data to the yield locus equation is defined as:

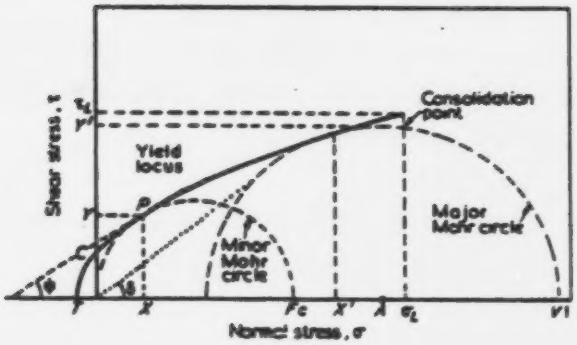
$$\text{Percentage Fit} = 100 [1 - \{ \sum (\tau_c - \tau_i)^2\} / \sum (\tau - \tau_i^2)] \qquad . . (A6)$$

where τ_c and τ_i are the calculated and experimental values. The percentage fit for each yield locus was calculated.

The unconfined yield strength (F_c), the major principal consolidating stress (V1), the effective angle of friction (δ) and the internal angle of friction (ϕ), (see Figure A1), were calculated iteratively for each yield locus.

FIGURE A1

A TYPICAL YIELD LOCUS


Shear stress, τ
τ_c
Y'
Y
Consolidation point
Yield locus
P
C
ϕ
δ
Minor Mohr circle
Major Mohr circle
T
X
Fc
X'
λ
σ_c
V1
Normal stress, σ

Fc = Unconfined yield strength

$V1$ = Major principal consolidating stress

δ = Effective angle of friction

ϕ = Angle of internal friction at a free arch

C = Cohesion

T = Tensile strength

The flow parameters were used to obtain material flow functions and hopper flow factors which in turn were used to evaluate the critical bin parameters as explained in the main body of the report under "Results".

The yield locus equation was found to fit well to shear test data for biomass with percentage fits of better than 98% for the majority of results.

TIME CONSOLIDATION

The limited amount of data for time consolidation tests (1 point per yield locus) made it necessary to assume values of n and K from "instantaneous" results of the same sample. The value of T in equation A4 was obtained iteratively.

From the values of C and T, the flow parameters were again determined iteratively as in the case of instantaneous results.

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APPENDIX B

DETAILED RESULTS OF SHEAR AND WALL FRICTION TESTS

Tables and figures for each sample are kept together for ease of reference in the following order:

Tables:
- a) Shear Test Results
- b) Flow Properties
- c) Wall Friction Test Results
- d) Time Consolidation Results

Figures:
- a) Material and Hopper Flow Factors
- b) Wall Friction Tests
- c) Particle Size Distribution

Some tables and figures for wall friction results and particle size data have not been included for tests repeated on samples at different temperatures, moisture contents or particle sizes. Appropriate data were assumed from previous tests.

The data are ordered according to sample type ie., hog fuel, chips, sawdust, peat, grain dust and by sample number.

TABLE B1 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR HOG FUEL (MB-CANADIAN WHITE PINE DIV.) SAMPLE # OOA

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
24.3	31.6	1.5	6.0
		2.9	8.0
		4.3	9.3
		9.0	15.8
		14.6	22.6
		21.0	29.2
		24.3	31.6
45.0	49.4	1.5	5.7
		2.9	8.7
		4.3	10.6
		9.0	22.9
		18.2	28.9
		33.9	43.4
		45.0	49.4
60.3	58.9	1.5	8.7
		2.9	9.3
		4.3	11.2
		9.0	19.1
		24.3	39.0
		45.0	49.6
		60.3	58.9
85.6	70.9	1.5	7.6
		4.3	14.5
		9.0	32.2
		45.0	53.5
		60.3	61.1
		70.4	63.8
		85.6	70.9
115.9	87.3	1.5	7.5
		4.3	14.2
		9.0	23.5
		24.3	46.4
		60.3	66.0
		85.6	76.9
		115.9	87.3

TABLE B1 (b)

CEDAR HOG FUEL (MB-CANADIAN WHITE PINE DIV.) SAMPLE # OOA (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
24.3	31.6	68.5	33.8	2.02	58.5	54.48	4.61	1.45
45.0	49.4	112.5	45.3	2.49	54.0	54.48	6.17	1.94
60.3	58.9	137.4	45.7	3.00	50.2	54.48	6.23	1.96
85.6	70.9	176.5	46.3	3.81	45.8	54.48	6.31	1.98
115.9	87.3	225.2	50.2	4.49	43.1	54.48	6.84	2.15

SHEAR INDEX (N) = 1.53

YIELD LOCUS	PERCENT FIT
1	99.4
2	99.1
3	99.5
4	98.3
5	98.7

TABLE B1 (c)

WALL FRICTION TEST RESULTS

HOG FUEL-MAINLY CEDAR (MB-CANADIAN WHITE PINE DIV.) SAMPLE 00A

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.4	103.1
150.4	89.1
122.3	74.4
94.2	58.9
66.2	43.5
52.1	33.7
38.1	26.0
24.1	16.8
10.0	8.4
4.8	4.2

WALL MATERIAL - RUSTY MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.4	115.8
150.4	101.0
122.3	82.1
94.2	64.6
66.2	47.0
52.1	37.9
38.1	28.1
24.1	18.2
10.0	7.7
4.8	3.5

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.4	45.6
150.4	39.3
122.3	33.0
94.2	26.0
66.2	19.6
52.1	16.8
38.1	13.3
24.1	9.1
10.0	4.9
4.8	2.8

TABLE B1 (c) con't

WALL FRICTION TEST RESULTS

HOG FUEL-MAINLY CEDAR (MB-CAN. WHITE PINE DIV.) SAMPLE 00A (CONT.)

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.4	80.0
150.4	67.4
122.3	55.4
94.2	42.8
66.2	32.3
52.1	26.7
38.1	20.3
24.1	14.0
10.0	7.7
4.8	4.9

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.4	127.0
150.4	110.2
122.3	92.6
94.2	73.0
66.2	51.9
52.1	41.4
38.1	30.2
24.1	19.6
10.0	9.1
4.8	4.2

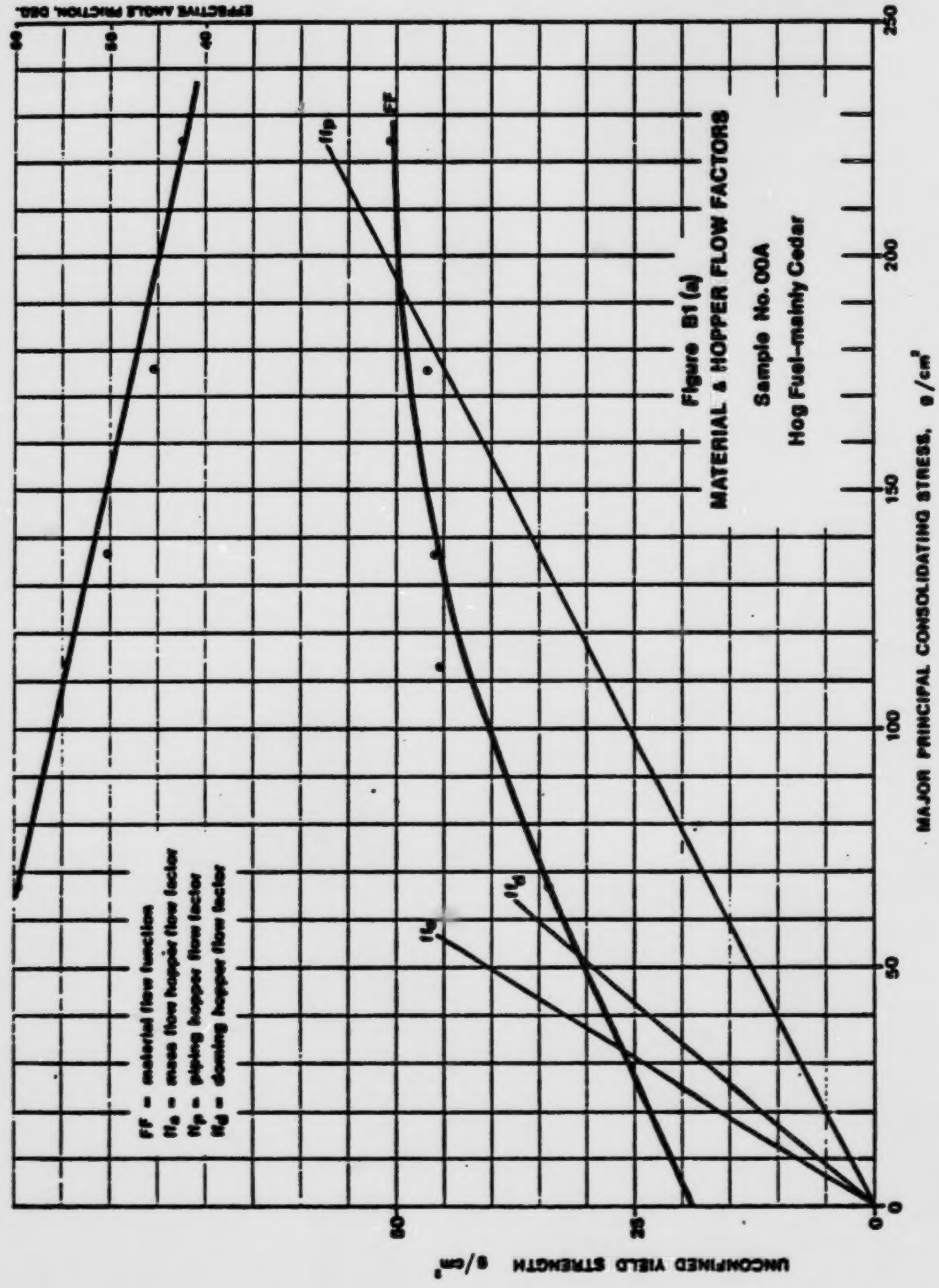

Figure B1 (a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 00A
Hog Fuel—mainly Cedar

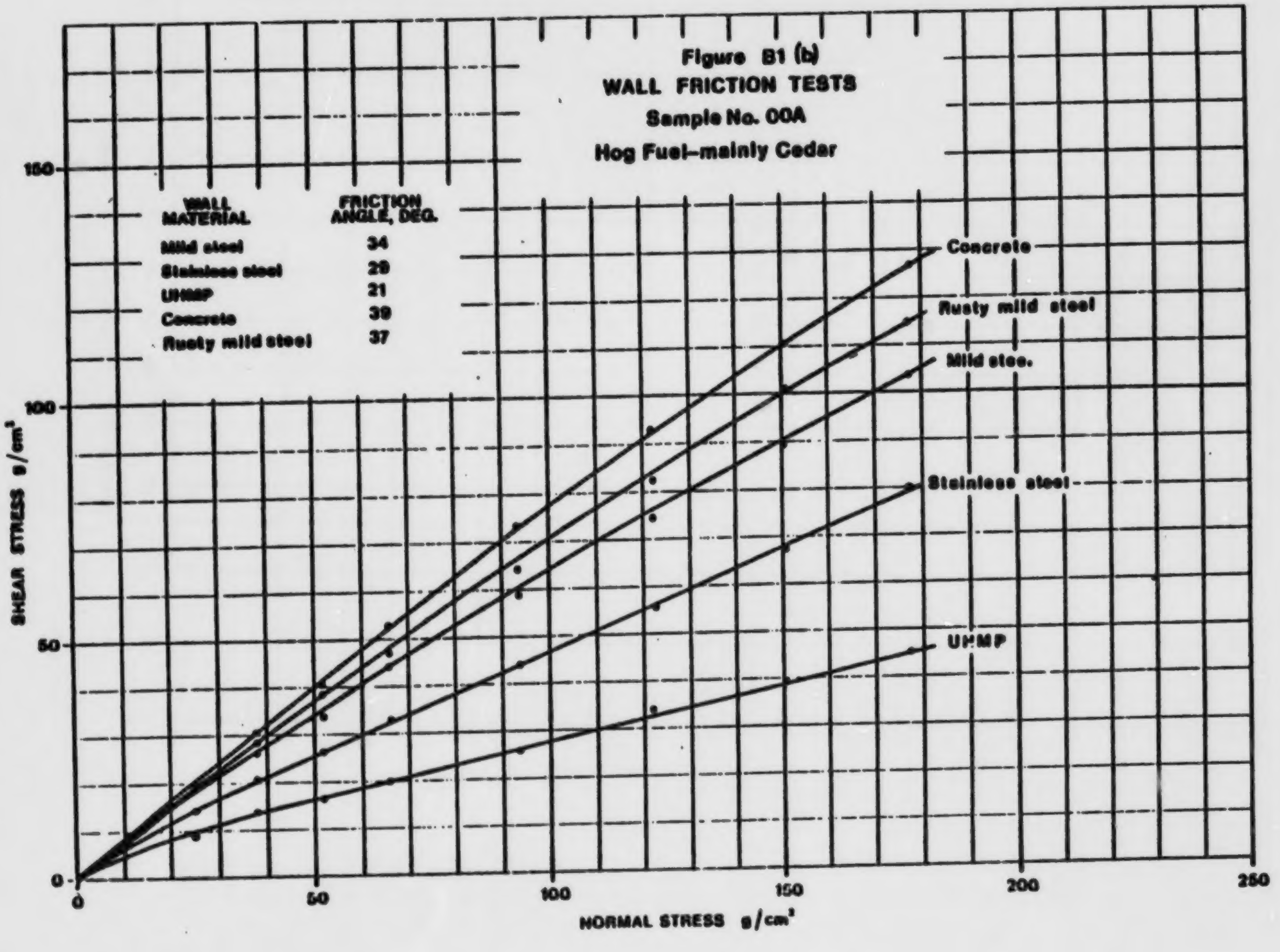

Figure B1 (b)
WALL FRICTION TESTS
Sample No. 00A
Hog Fuel-mainly Cedar

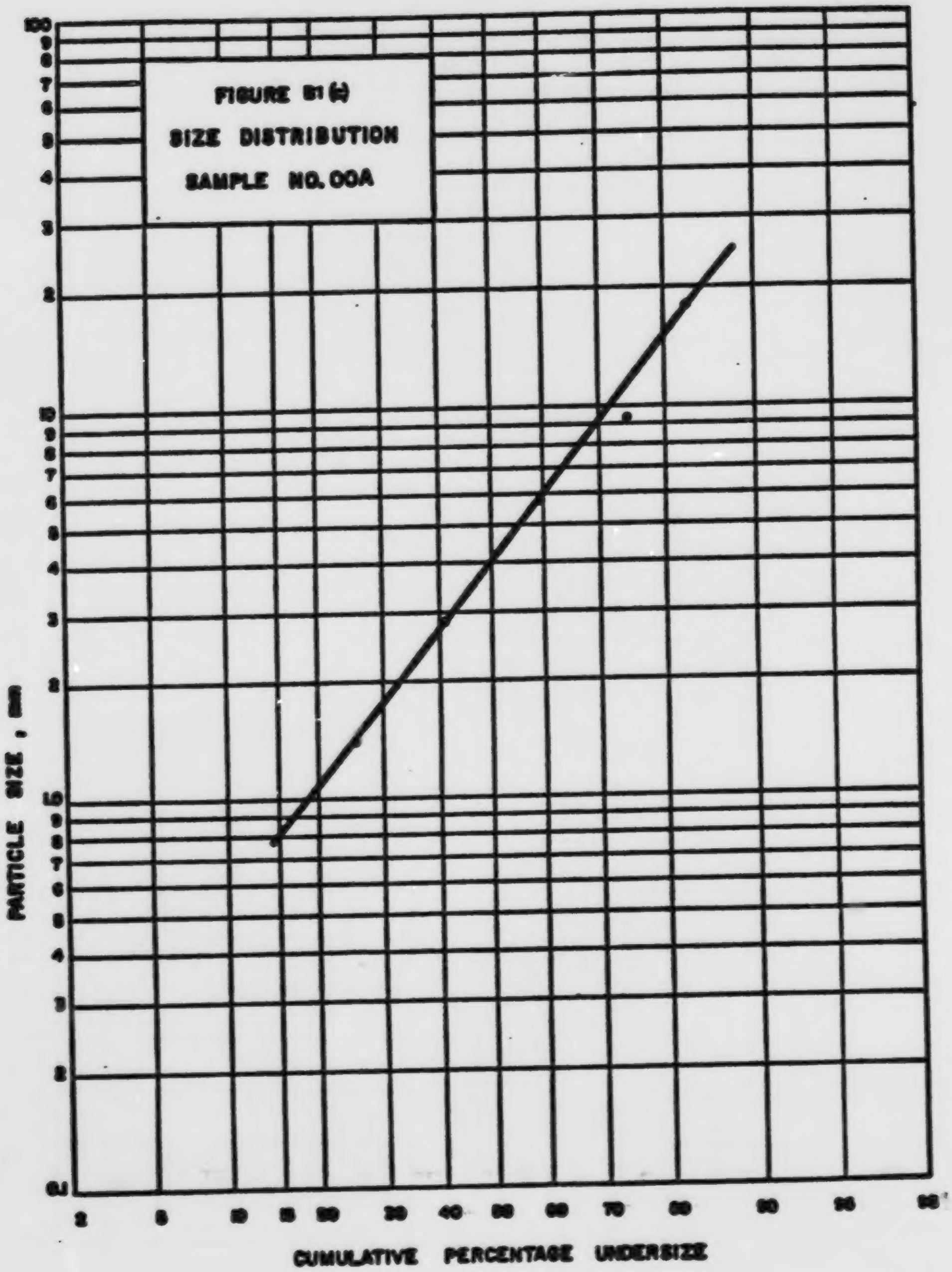

FIGURE B1(c)
SIZE DISTRIBUTION
SAMPLE NO. OOA

TABLE B2 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR HOG FUEL (MB-CANADIAN WHITE PINE DIV.) SAMPLE # 008

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
24.3	27.0		
		1.5	3.5
		2.9	4.6
		4.3	7.0
		9.0	11.9
		14.6	17.7
		21.0	22.1
		24.3	27.0
45.0	39.0		
		1.5	4.6
		2.9	6.5
		4.3	9.0
		9.0	14.5
		18.2	24.0
		33.9	32.2
		45.0	39.0
60.3	51.3		
		1.5	3.9
		2.9	6.0
		4.3	8.7
		9.0	18.0
		24.3	32.7
		45.0	44.7
		60.3	51.3
85.6	69.8		
		1.5	3.5
		4.3	10.2
		9.0	16.3
		45.0	46.9
		60.3	56.2
		70.4	60.0
		85.6	69.8
115.9	86.2		
		1.5	4.1
		4.3	9.4
		9.0	18.2
		24.3	37.1
		60.3	61.6
		85.6	76.4
		115.9	86.2

TABLE B2 (b)

CEDAR HOG FUEL (MB-CANADIAN WHITE PINE DIV.) SAMPLE # 008 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
24.3	27.0	58.1	16.1	3.62	49.7	53.38	2.39	.97
45.0	39.0	95.7	19.0	5.04	45.1	53.38	2.83	1.15
60.3	51.3	128.4	25.6	5.02	45.1	53.38	3.81	1.55
85.6	69.8	171.1	27.6	6.20	42.4	53.38	4.11	1.67
115.9	86.2	225.5	33.0	6.84	41.2	53.38	4.91	2.00

SHEAR INDEX (N) = 1.39

YIELD LOCUS	PERCENT FIT
1	99.2
2	99.6
3	99.1
4	99.8
5	99.3

TABLE B2 (c)

WALL FRICTION TEST RESULTS

HOG FUEL-MAINLY CEDAR (MB - CANADIAN WHITE PINE DIV.) SAMPLE 008

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	103.1
150.2	89.1
122.1	74.4
94.1	58.2
66.0	42.1
52.0	34.4
37.9	25.3
23.9	16.8
9.9	8.4
4.6	4.9

WALL MATERIAL - RUSTY MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	108.8
150.2	94.7
122.1	76.5
94.1	59.6
66.0	43.5
52.0	33.7
37.9	24.6
23.9	15.4
9.9	5.6
4.6	2.8

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	40.7
150.2	35.1
122.1	28.8
94.1	23.2
66.0	16.8
52.0	13.3
37.9	10.5
23.9	7.0
9.9	3.5
4.6	1.4

TABLE B2 (c) con't

WALL FRICTION TEST RESULTS

HOG FUEL-MAINLY CEDAR (MB-CAN. WHITE PINE DIV.) SAMPLE 008 (CONT.)

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	72.3
150.2	61.7
122.1	51.2
94.1	40.7
66.0	30.2
52.0	23.9
37.9	17.5
23.9	11.9
9.9	4.9
4.6	2.8

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	113.0
150.2	94.0
122.1	77.2
94.1	59.6
66.0	43.5
52.0	34.4
37.9	26.7
23.9	17.5
9.9	7.7
4.6	3.5

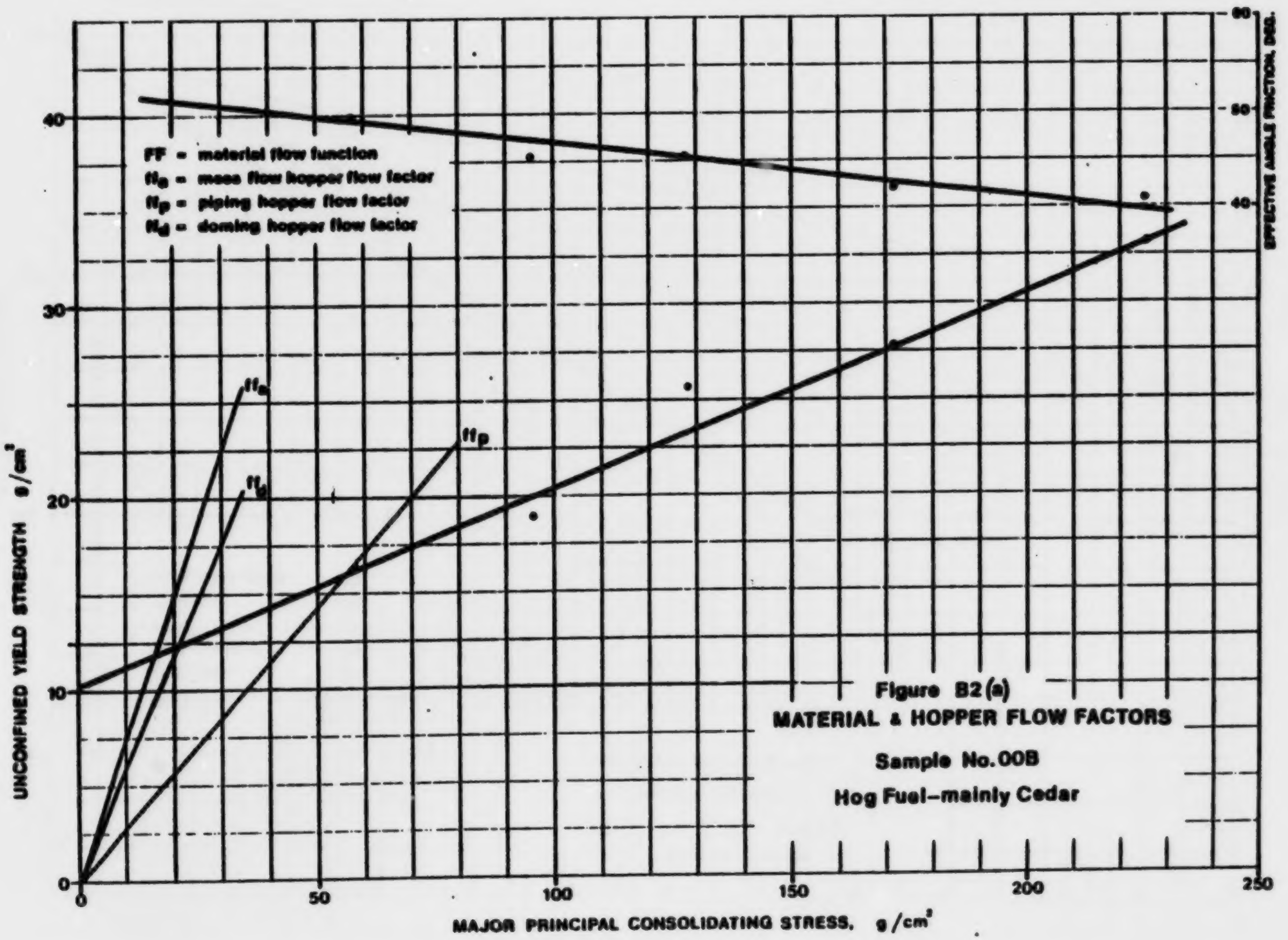

Figure B2(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 00B
Hog Fuel–mainly Cedar

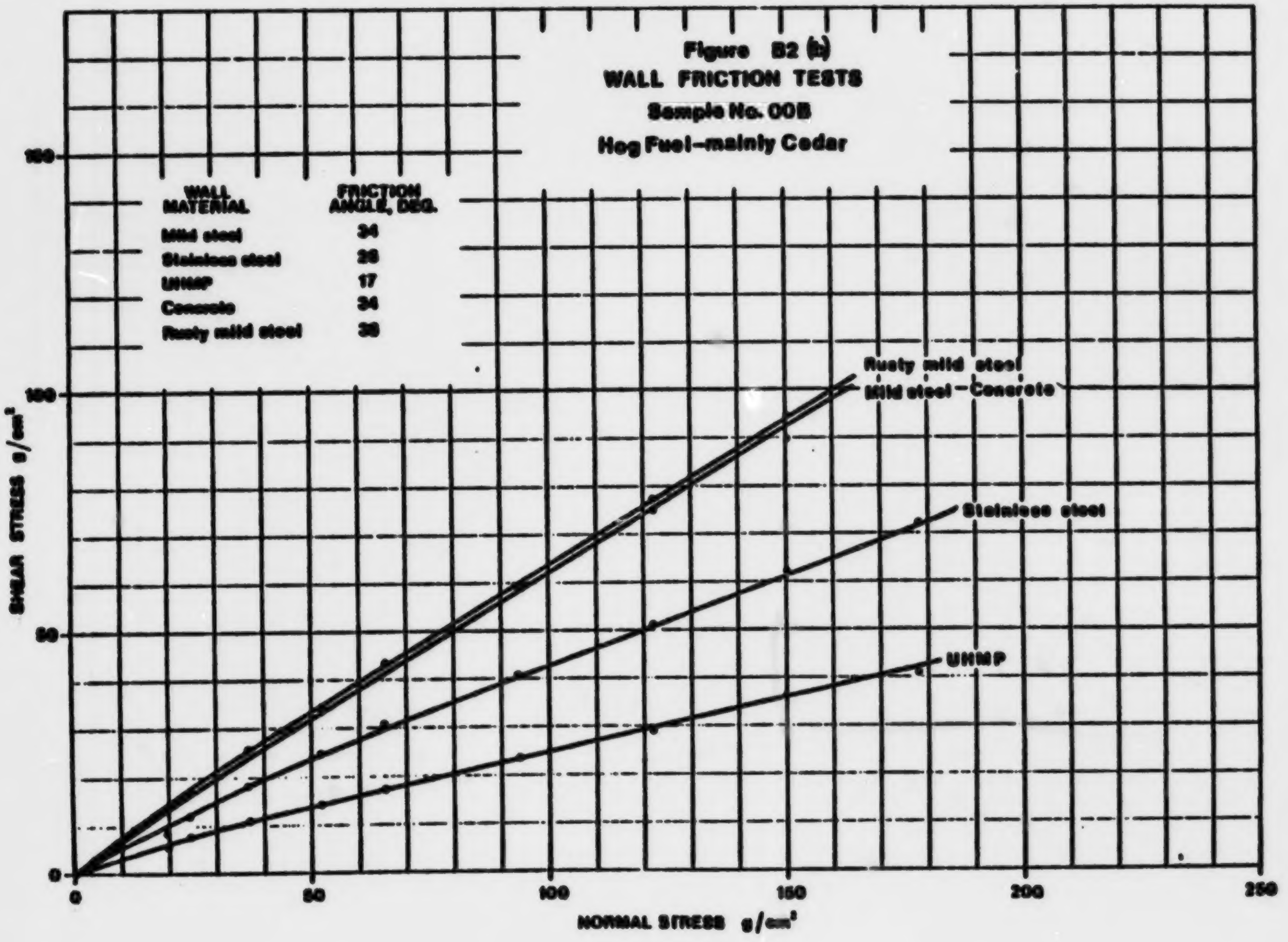

Figure B2 (b)
WALL FRICTION TESTS
Sample No. 00B
Hog Fuel–mainly Cedar

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	34
Stainless steel	26
UHMP	17
Concrete	34
Rusty mild steel	36

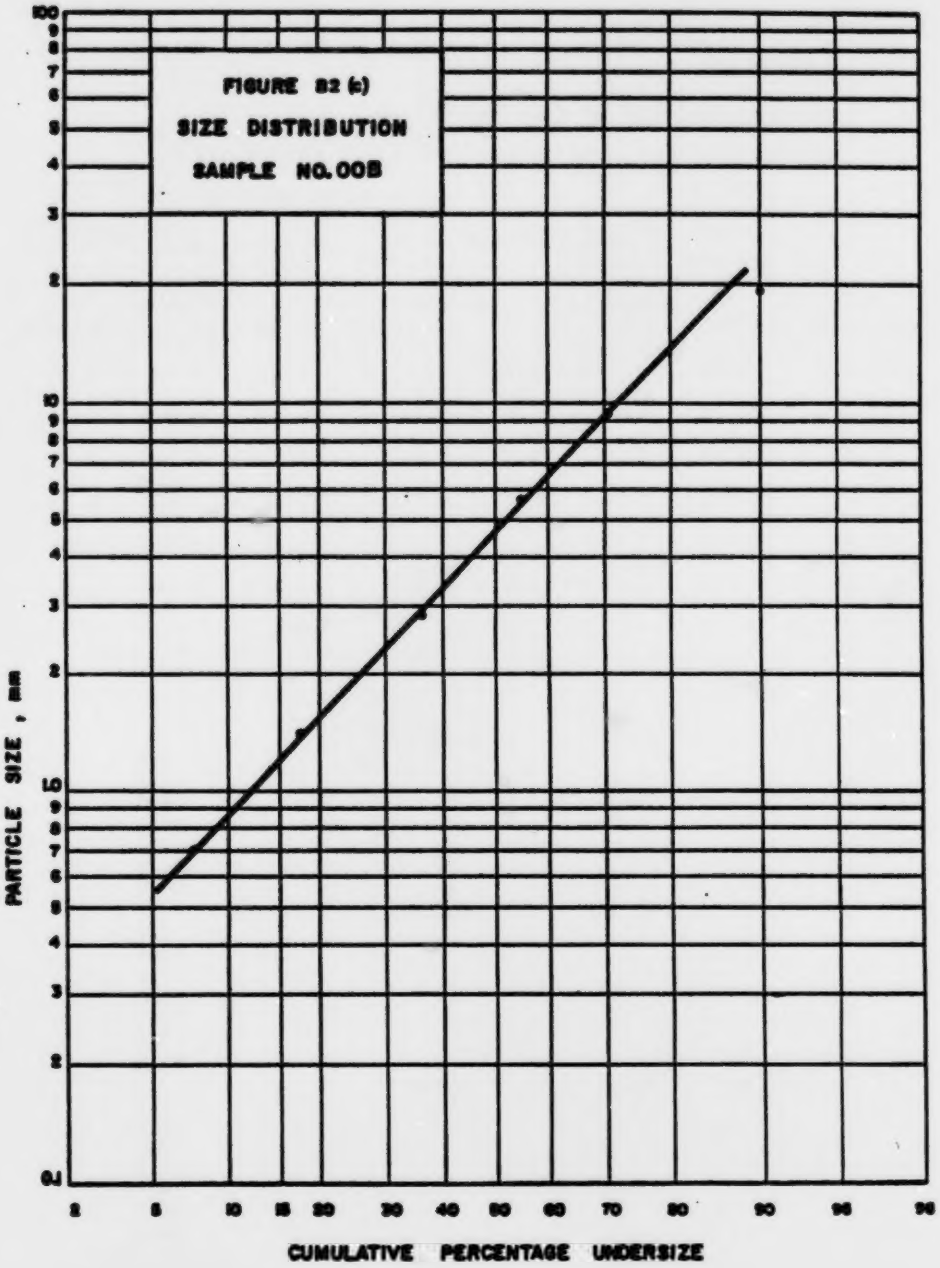

FIGURE 82 (c)
SIZE DISTRIBUTION
SAMPLE NO. 008

TABLE 83 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK HOG FUEL - MB (WHITE PINE DIV.) SAMPLE 021

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	43.7	2.5	10.7
		4.2	11.1
		8.4	17.8
		12.6	23.8
		16.8	25.0
		24.4	40.7
		27.0	43.7
48.1	60.5	4.2	10.8
		8.4	24.3
		16.8	31.0
		27.0	39.8
		33.7	57.9
		39.6	63.1
		48.1	60.5
59.9	90.0	4.2	18.3
		8.4	34.3
		16.8	52.4
		27.0	55.7
		43.8	68.6
		56.5	78.1
		59.9	90.0
81.8	106.8	4.2	25.3
		12.6	41.6
		27.0	71.8
		56.5	89.2
		59.9	90.9
		73.4	101.8
		81.8	106.8
98.7	131.0	4.2	22.5
		12.6	33.4
		27.0	57.2
		56.5	81.1
		73.4	111.7
		90.3	128.2
		98.7	131.0
115.6	149.8	4.2	24.7
		12.6	36.8
		27.0	58.7
		56.5	91.7
		81.8	115.4
		107.1	148.5
		115.6	149.8

TABLE B3 (b)

HEMLOCK HOG FUEL - MB (WHITE PINE DIV.) SAMPLE 021 (CONT.)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	43.7	91.4	49.1	1.86	63.9	59.91	5.42	1.29
48.1	60.5	146.1	68.0	2.15	60.5	59.91	7.50	1.78
59.9	90.0	202.5	108.5	1.87	63.8	59.92	11.98	2.84
81.8	106.8	256.5	124.5	2.06	61.4	59.92	13.73	3.26
98.7	131.0	293.2	131.9	2.22	59.7	59.92	14.55	3.45
115.6	149.8	335.4	145.8	2.30	59.0	59.91	16.09	3.82

SHEAR INDEX (N) = 1.55

YIELD LOCUS	PERCENT FIT
1	98.4
2	98.5
3	98.9
4	99.2
5	99.5
6	99.8

TABLE B3 (c)

WALL FRICTION TEST RESULTS

HEMLOCK HOG FUEL (MB - WHITE PINE DIV.) SAMPLE 021

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	49.8
67.3	44.7
58.8	39.6
50.4	32.0
42.0	27.1
33.5	22.2
25.0	17.6
16.6	11.6
8.1	5.9
3.7	2.5

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	48.4
67.3	43.2
58.8	38.2
50.4	33.0
42.0	27.8
33.5	22.4
25.0	16.8
16.6	11.2
8.1	5.4
3.7	2.3

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	21.3
67.3	17.7
58.8	15.4
50.4	13.3
42.0	11.3
33.5	9.5
25.0	7.0
16.6	4.8
8.1	2.3
3.7	.9

TABLE B3 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

HEMLOCK HOG FUEL SAMPLE # 021

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<---------------FLOW PROPERTIES--------------->					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS		UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
				INST	TIME				
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20									
48.1	62.4	48.1	70.5	146.1	162.5	86.7	63.7	59.9	9.57
81.8	100.5	81.8	115.3	256.5	264.2	132.9	62.3	59.9	14.68
CONSOLIDATION PERIOD 95 HOURS									
48.1	68.6	48.1	73.6	146.1	170.8	96.8	65.2	59.9	10.69

SHEAR INDEX (N) = 1.55

COHESION/ TENSILE
STRENGTH = 4.20

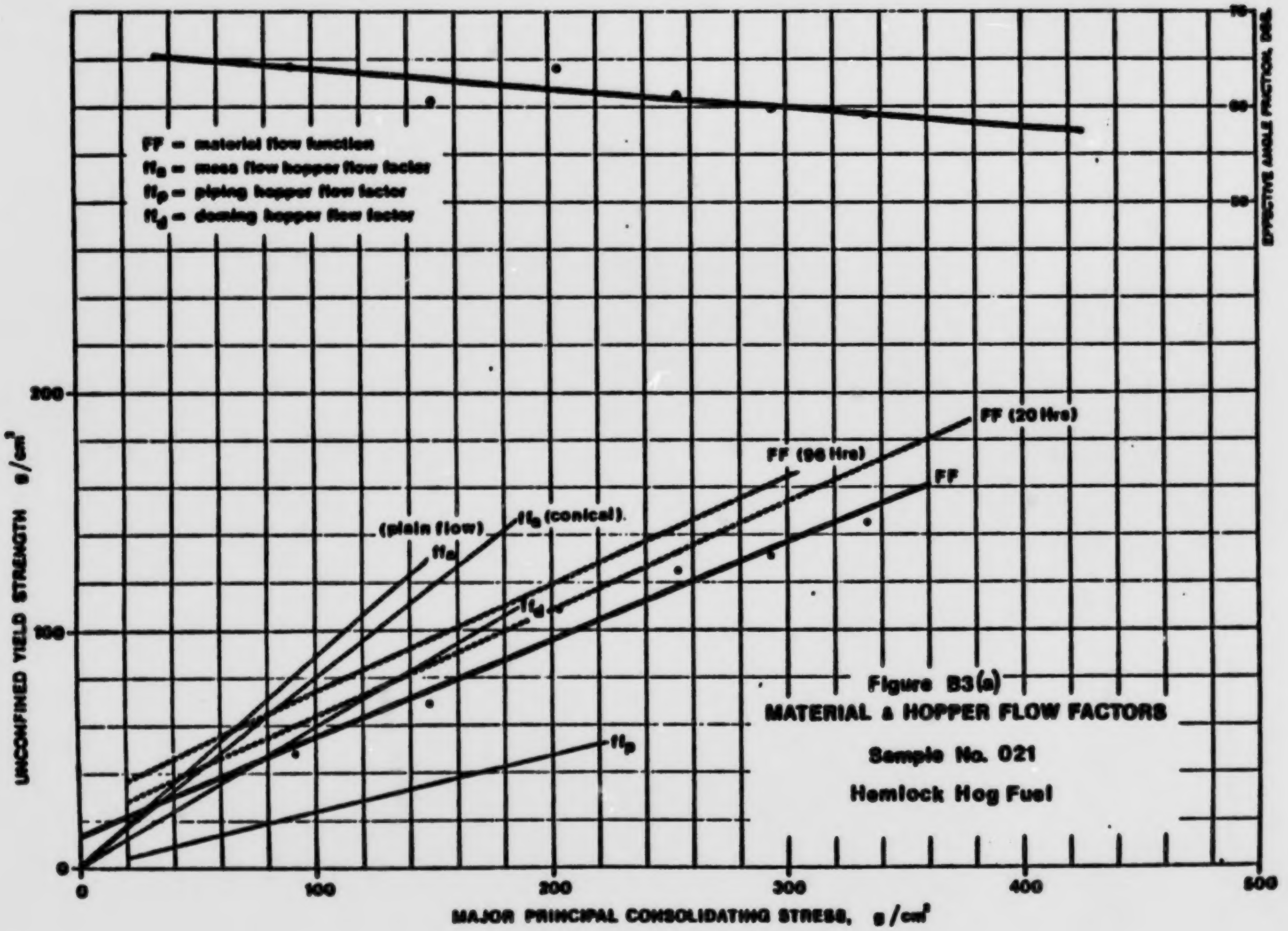

Figure B3(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 021
Hemlock Hog Fuel

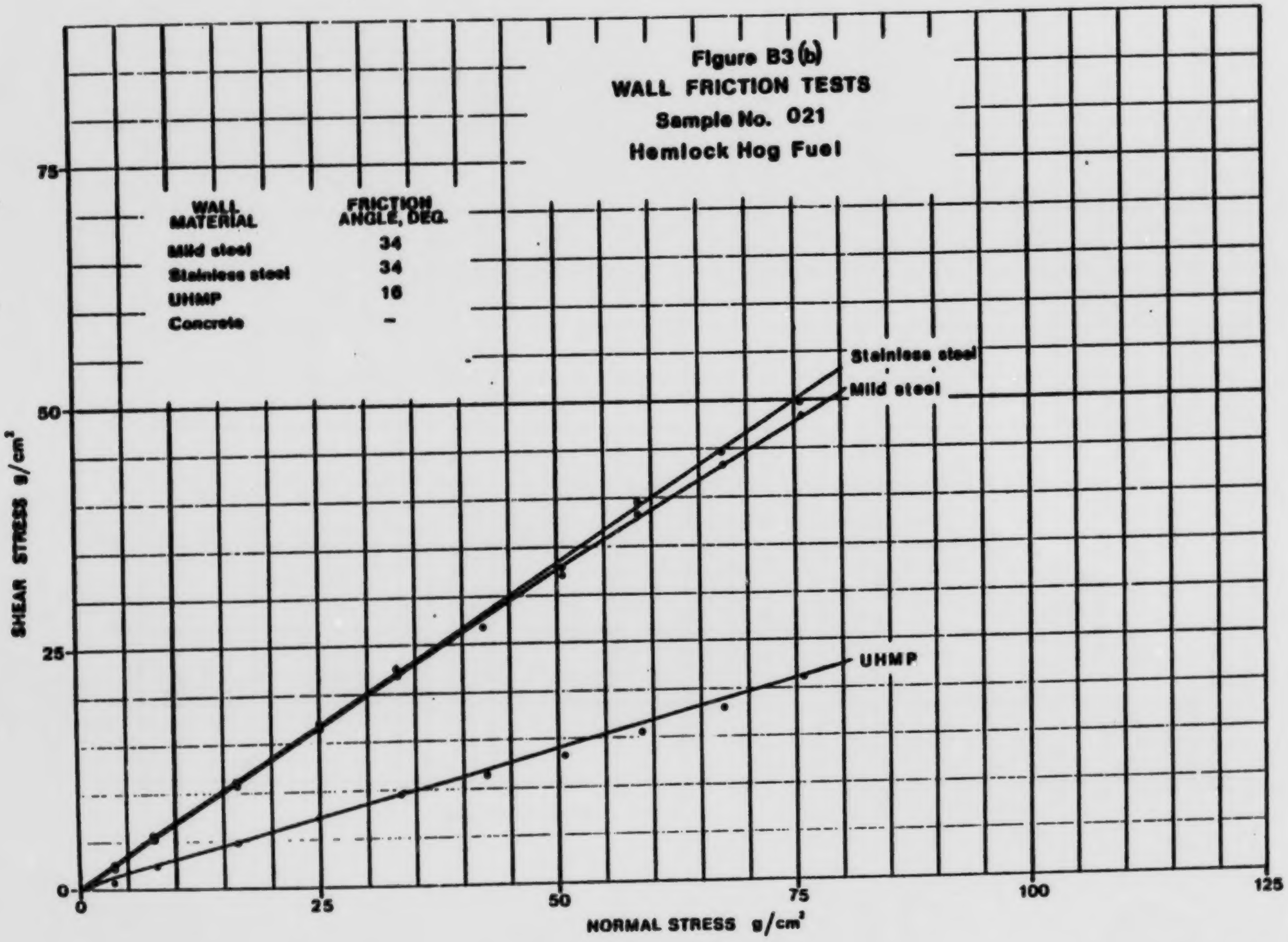

Figure B3 (b)
WALL FRICTION TESTS
Sample No. 021
Hemlock Hog Fuel

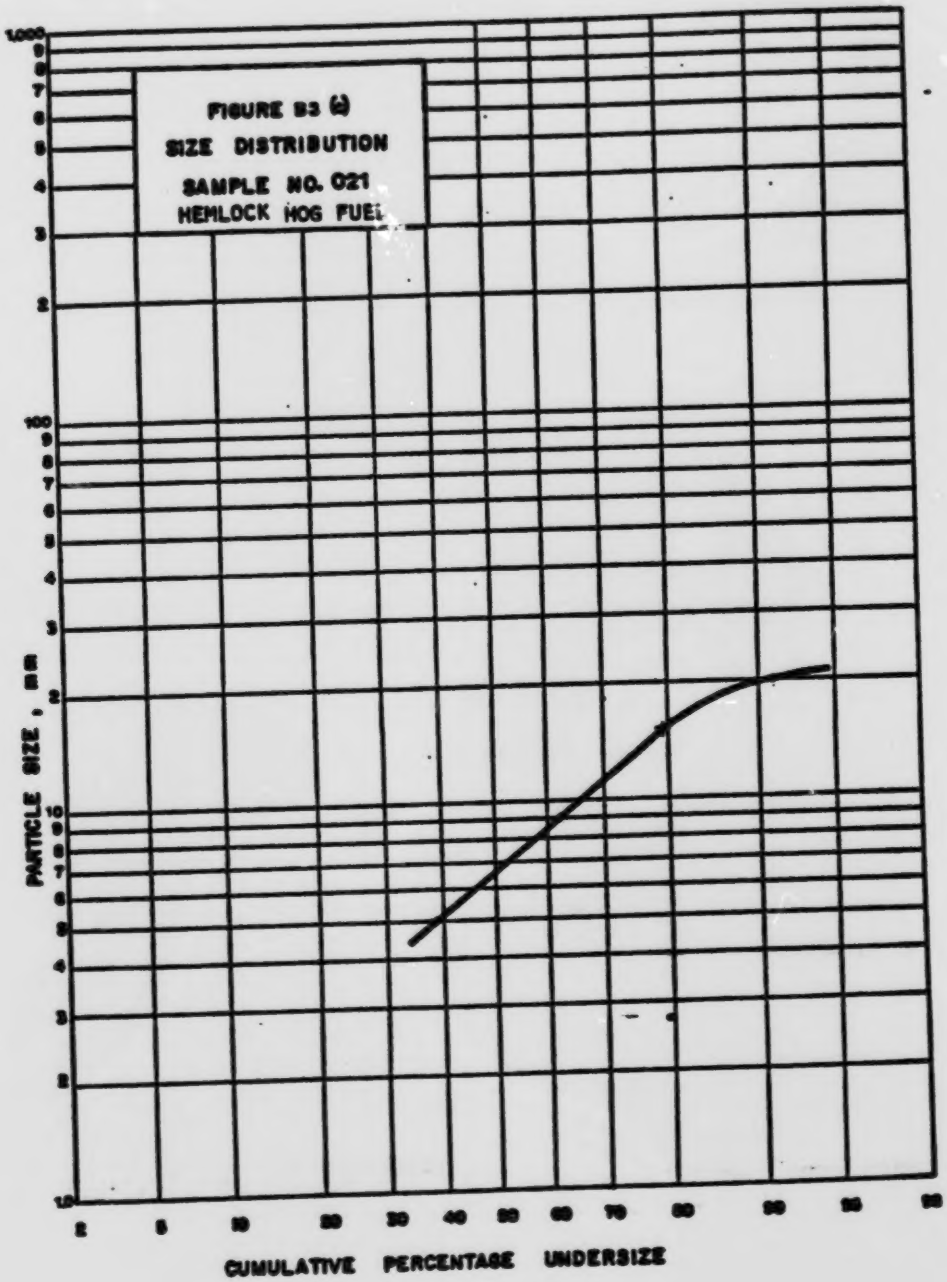

FIGURE B3 (c)
SIZE DISTRIBUTION
SAMPLE NO. 021
HEMLOCK HOG FUEL

TABLE B4 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK HOG FUEL (MB-CAN. WHITE PINE DIV.) SAMPLE # 021-A

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	33.7	2.5	6.7
		4.2	9.8
		8.4	14.9
		12.6	19.8
		16.8	23.8
		24.4	32.4
		27.0	33.7
48.1	63.8	4.2	10.9
		8.4	16.6
		16.8	27.2
		27.0	38.6
		33.7	43.1
		39.5	53.0
		48.1	63.8
59.9	72.1	4.2	13.7
		8.4	20.4
		16.8	34.6
		27.0	40.2
		43.8	63.3
		56.5	64.6
		59.9	72.1
81.8	94.2	4.2	15.5
		12.6	28.4
		27.0	42.2
		56.5	72.6
		59.9	86.4
		73.4	88.7
		81.8	94.2
98.7	121.1	4.2	28.5
		12.6	35.6
		27.0	46.8
		56.5	85.1
		73.4	97.1
		90.3	112.3
		98.7	121.1
115.6	124.8	4.2	16.2
		12.6	36.4
		27.0	63.8
		56.5	81.7
		81.8	101.3
		107.1	121.1
		115.6	124.8

TABLE B4 (b)

HEMLOCK HOG FUEL (MB-CAN. WHITE PINE DIV.) SAMPLE # 021-A (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	33.7	77.2	26.5	2.91	56.4	59.20	3.16	.93
48.1	63.8	135.7	45.4	2.99	55.9	59.20	5.42	1.59
59.9	72.1	166.3	53.9	3.09	55.4	59.20	6.43	1.89
81.8	94.2	222.3	68.9	3.23	54.6	59.20	8.23	2.42
98.7	121.1	279.4	93.8	2.98	56.0	59.20	11.20	3.29
115.6	124.8	300.1	84.6	3.55	53.1	59.20	10.11	2.97

SHEAR INDEX (N) = 1.45

YIELD LOCUS	PERCENT FIT
1	99.8
2	99.3
3	99.5
4	99.6
5	99.7
6	99.4

TABLE B4 (c)

WALL FRICTION TEST RESULTS

HEMLOCK HOG FUEL (MB - WHITE PINE DIV.) SAMPLE 021A

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	41.6
68.1	37.3
59.6	33.0
51.2	28.6
42.8	24.2
34.3	19.9
25.9	15.7
17.4	11.2
8.9	6.6
4.5	3.7

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	44.8
68.1	40.5
59.6	35.6
51.2	31.0
42.8	26.3
34.3	21.7
25.9	17.0
17.4	12.1
8.9	7.1
4.5	3.9

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (1)

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	22.6
68.1	20.3
59.6	17.8
51.2	15.6
42.8	13.2
34.3	10.9
25.9	8.6
17.4	6.2
8.9	3.7
4.5	2.2

TABLE B4 (c) con't

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (2)

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	21.5
68.1	19.4
59.6	17.2
51.2	14.9
42.8	13.2
34.3	10.6
25.9	8.4
17.4	6.0
8.9	3.7
4.5	2.2

WALL MATERIAL - ALUMINIUM

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	40.9
68.1	36.8
59.6	32.5
51.2	28.2
42.8	23.8
34.3	19.6
25.9	15.3
17.4	10.9
8.9	6.3
4.5	3.4

TABLE B4 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

HEMLOCK HOG FUEL SAMPLE # 021-A
                             - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT     <--------------FLOW PROPERTIES---------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC    UNCONFIN  EFFECT  INTERNAL  COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N     YIELD     FRIC    FRIC ANG
                                 STRESS      STRESS    ANGLE   AT FREE
                                INST  TIME                      SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM     G/SQ CM   DEG      DEG      G/SQ CM


CONSOLIDATION PERIOD  20 HOURS

  48.1   53.4    48.1    62.5  135.7  145.2   56.2     58.2     59.0      6.76
  48.1   54.3    48.1    60.5  135.7  140.3   51.1     57.1     59.0      6.14
  81.8   87.4    81.8   103.2  222.3  239.2   87.4     57.2     59.0     10.49

CONSOLIDATION PERIOD  68 HOURS

  81.8   97.3    81.8   119.2  222.3  280.5  133.2     62.1     59.0     16.00


                        SHEAR INDEX (N)    =   1.45

                        COHESION/ TENSILE
                               STRENGTH =   3.40
```

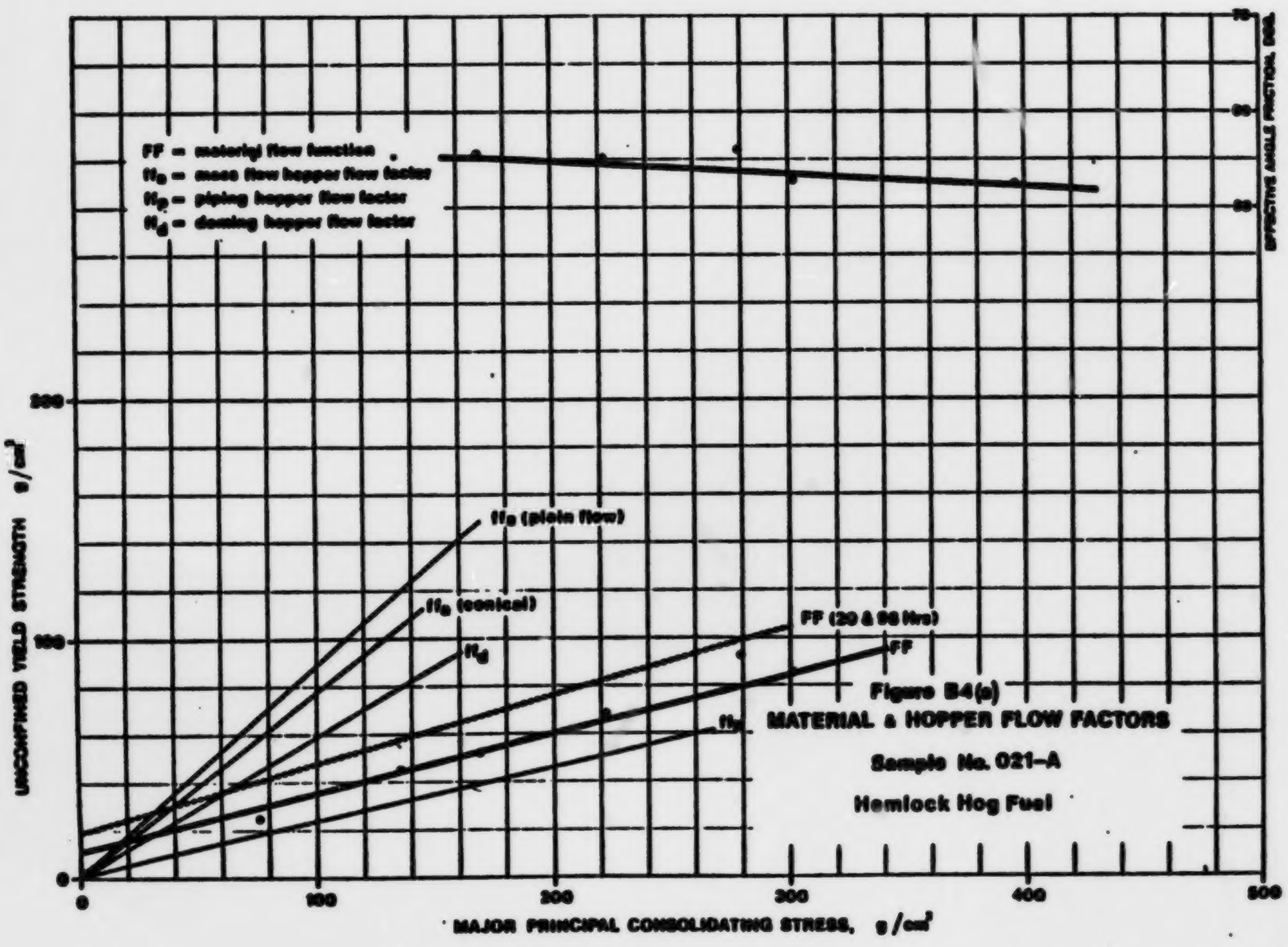

Figure B4(a)

MATERIAL & HOPPER FLOW FACTORS

Sample No. 021-A

Hemlock Hog Fuel

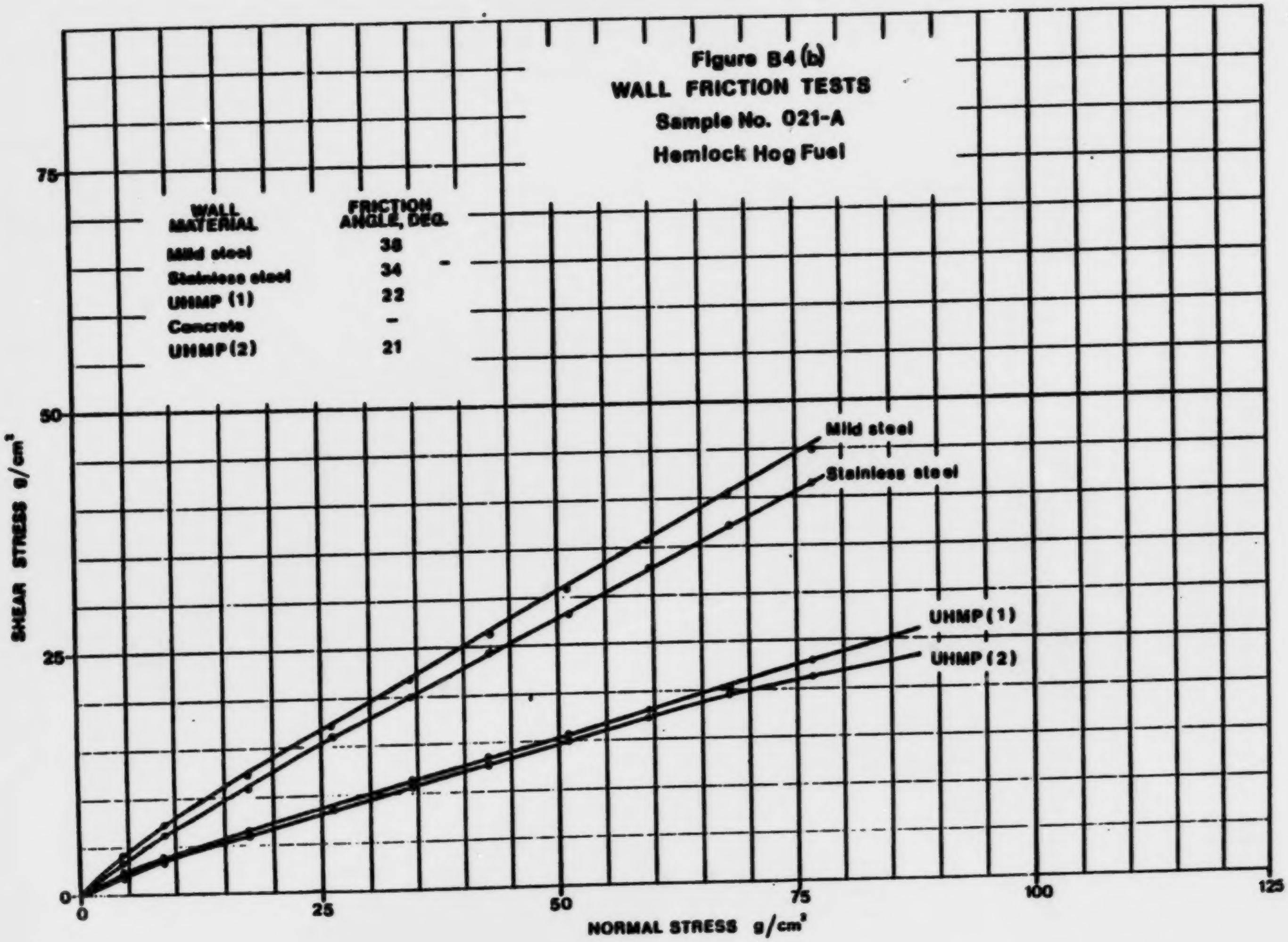

Figure B4 (b)
WALL FRICTION TESTS
Sample No. 021-A
Hemlock Hog Fuel

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	38
Stainless steel	34
UHMP (1)	22
Concrete	–
UHMP (2)	21

TABLE B5 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

FIR HOG FUEL (MB-CAN.WHITE PINE DIV.) SAMPLE 022

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	36.1		
		2.5	7.4
		4.2	18.3
		8.4	19.0
		12.6	22.2
		16.8	25.0
		24.4	32.4
		27.0	36.1
48.1	68.0		
		4.2	18.0
		8.4	24.1
		16.8	37.7
		27.0	48.4
		33.7	52.0
		39.6	64.3
		48.1	68.0
59.9	87.9		
		4.2	20.0
		8.4	31.8
		16.8	43.1
		27.0	57.2
		43.8	79.9
		56.5	85.5
		59.9	87.9
81.8	107.8		
		4.2	22.5
		12.6	35.2
		27.0	57.7
		56.5	79.5
		59.9	93.1
		73.4	102.3
		81.8	107.8
98.7	129.8		
		4.2	18.1
		12.6	36.9
		27.0	60.0
		56.5	85.0
		73.4	110.3
		90.3	129.2
		98.7	129.8
115.6	161.0		
		4.2	20.3
		12.6	40.2
		27.0	80.4
		56.5	112.9
		81.8	114.5
		107.1	151.0
		115.6	161.0

TABLE B5 (b)

FIR HOG FUEL (MB-CAN.WHITE PINE DIV.) SAMPLE 022 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	36.1	79.2	41.8	1.90	61.1	57.87	4.82	1.13
48.1	68.0	152.4	88.4	1.72	63.6	57.87	10.21	2.38
59.9	87.9	202.7	126.9	1.60	65.8	57.87	14.66	3.42
81.8	107.8	239.1	125.2	1.91	60.9	57.87	14.46	3.38
98.7	129.8	286.5	148.7	1.93	60.6	57.87	17.17	4.01
115.6	161.0	350.7	192.8	1.82	62.2	57.87	22.26	5.20

SHEAR INDEX (N) = 1.61

YIELD LOCUS	PERCENT FIT
1	98.6
2	99.8
3	99.8
4	99.8
5	99.5
6	99.0

TABLE B5 (c)

WALL FRICTION TEST RESULTS

FIR HOG FUEL (MB - CAN. WHITE PINE DIV.) SAMPLE 022

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	50.5
67.3	45.5
58.8	40.5
50.4	35.1
42.0	29.9
33.5	24.6
25.0	19.0
16.6	13.1
8.1	6.8
3.7	3.0

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	45.9
67.3	41.6
58.8	36.6
50.4	32.1
42.0	27.3
33.5	22.4
25.0	17.6
16.6	12.4
8.1	6.7
3.7	2.6

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	29.2
67.3	26.2
58.8	23.7
50.4	21.1
42.0	18.3
33.5	14.1
25.0	11.5
16.6	8.7
8.1	3.0
3.7	1.6

TABLE B5 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

FIR HOG FUEL SAMPLE # 022

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<---------------FLOW PROPERTIES--------------->					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS		UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
				INST	TIME				
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20 HOURS									
27.0	39.9	27.0	41.5	79.2	94.5	61.2	66.8	57.9	7.07
48.1	55.9	48.1	68.5	152.4	154.4	90.6	64.0	57.9	10.47
48.1	62.0	48.1	64.3	152.4	144.0	77.5	61.6	57.9	8.95
98.7	113.9	98.7	126.4	286.5	282.3	142.8	60.0	57.9	16.50
CONSOLIDATION PERIOD 88 HOURS									
48.1	56.2	48.1	63.6	152.4	142.5	75.6	61.3	57.9	8.74

SHEAR INDEX (N) = 1.61

COHESION/ TENSILE
STRENGTH = 4.27

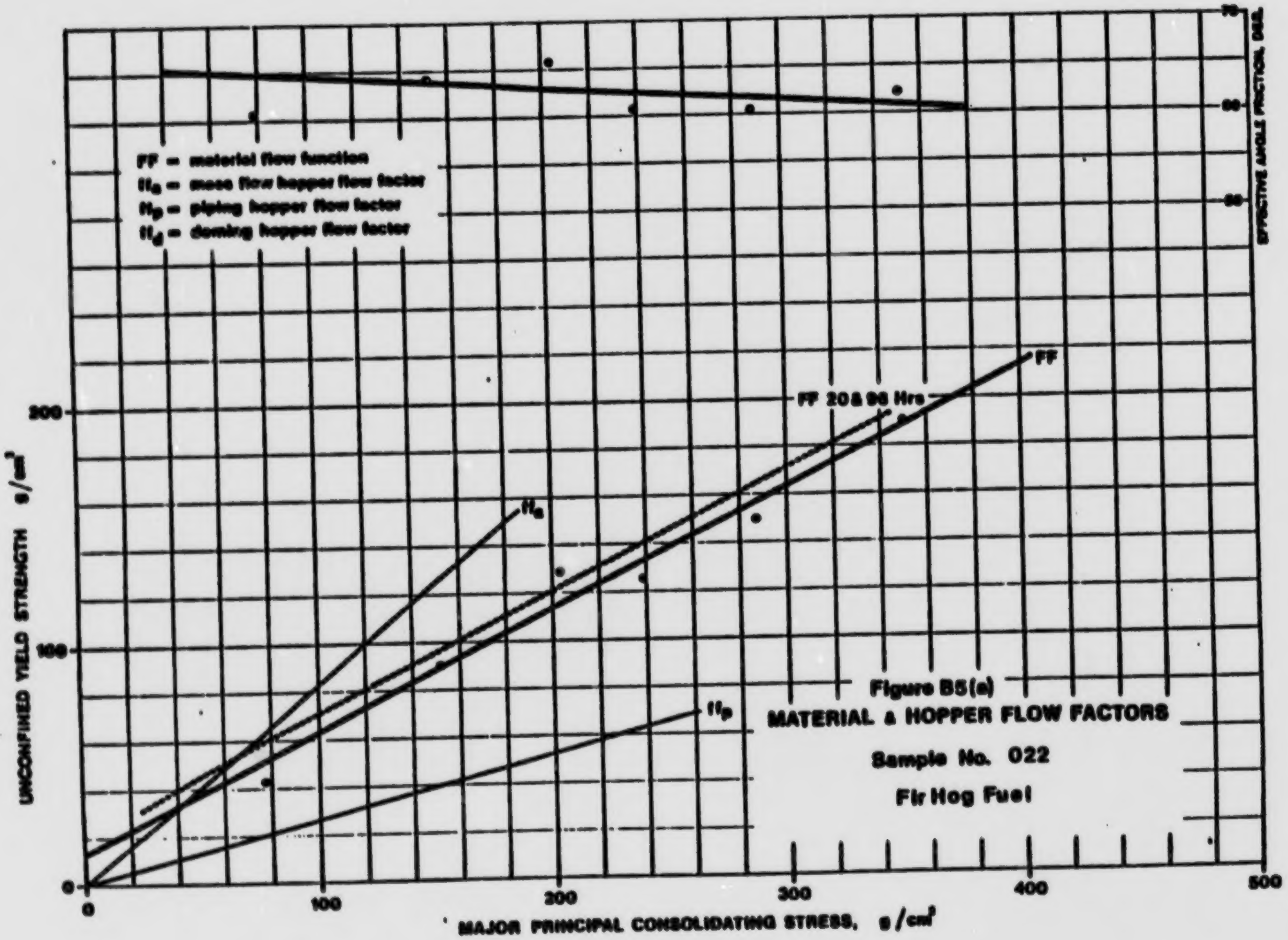

Figure B5(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 022
Fir Hog Fuel

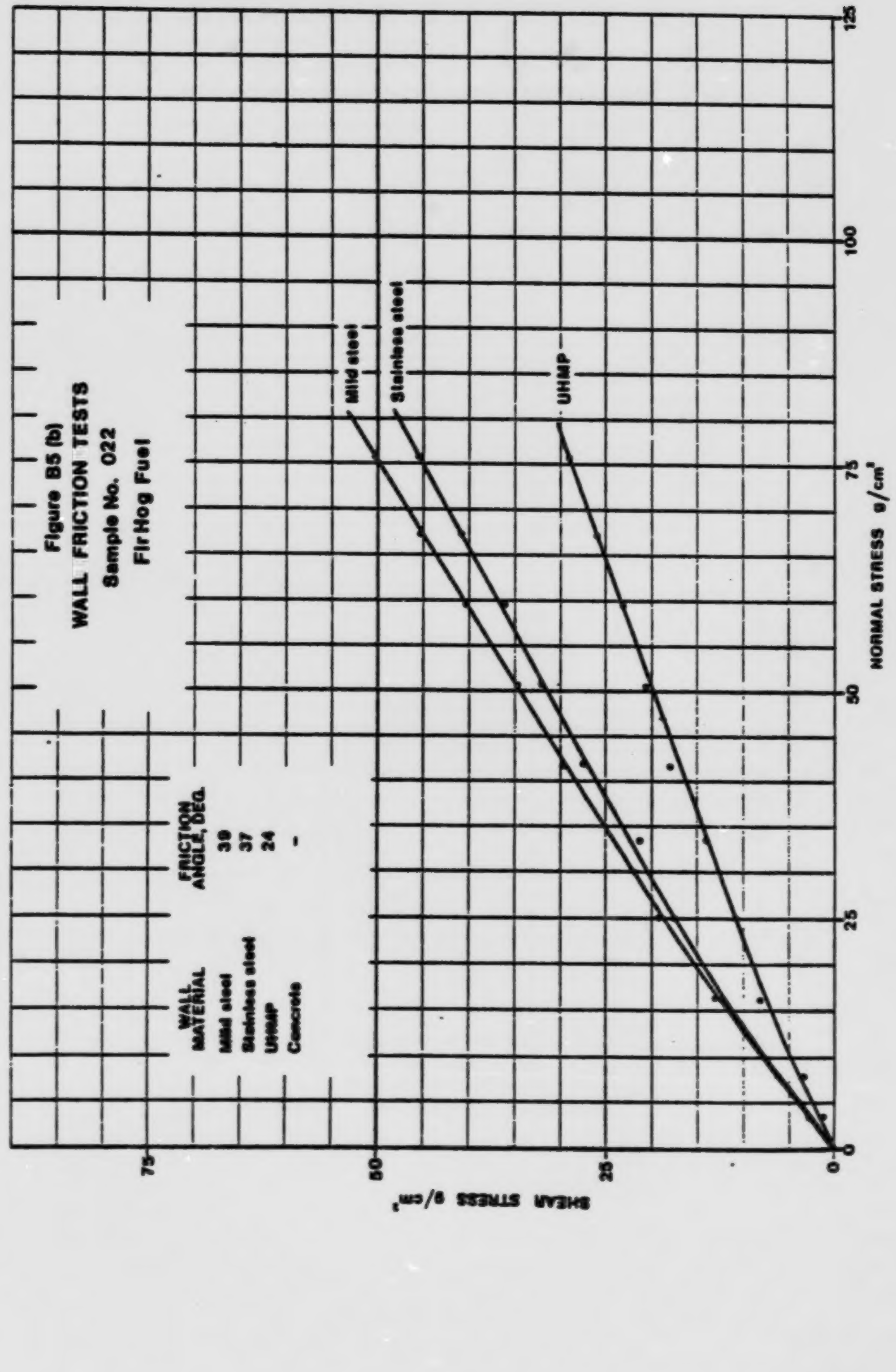

Figure B5 (b)
WALL FRICTION TESTS
Sample No. 022
Fir Hog Fuel

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	39
Stainless steel	37
UHMP	24
Concrete	-

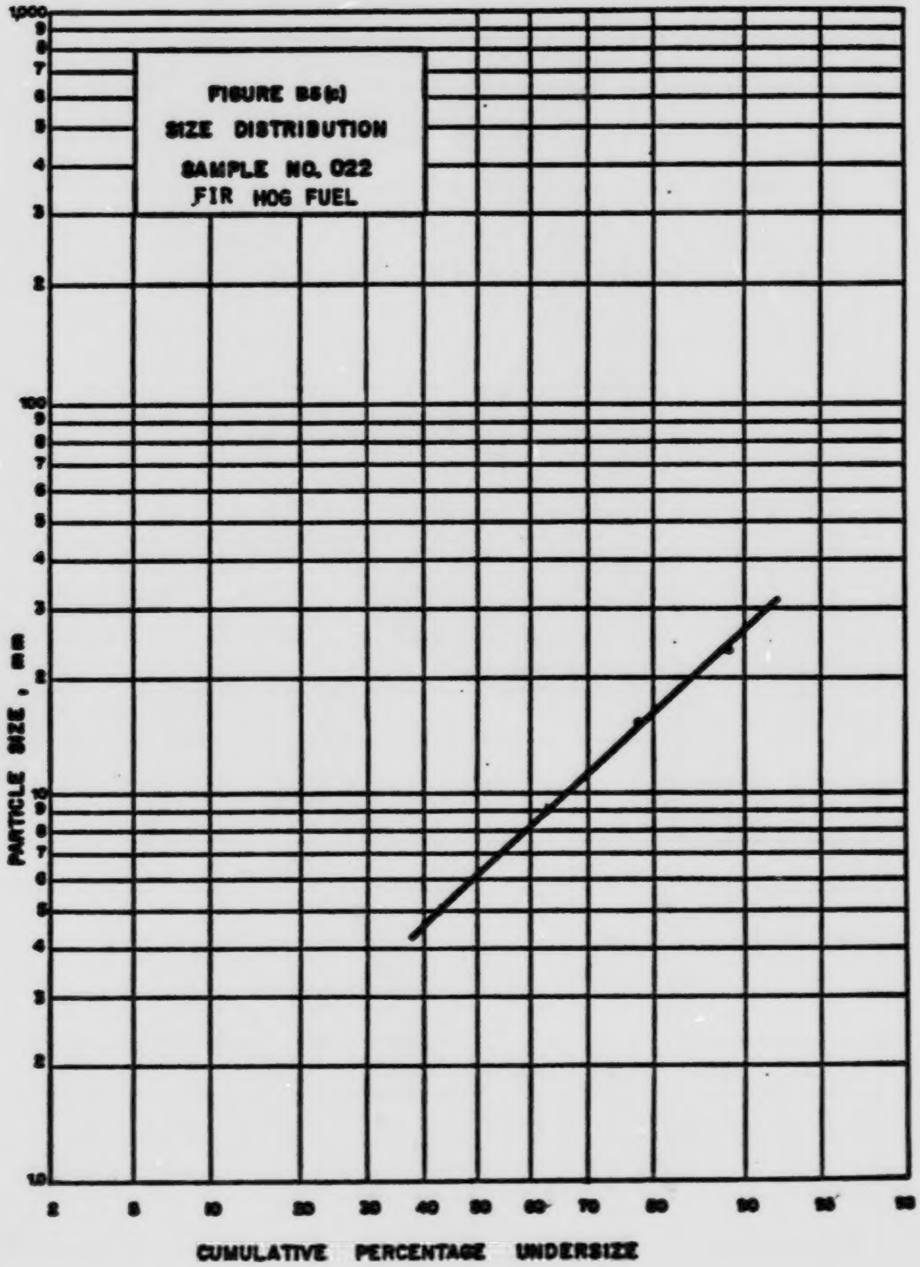

FIGURE B5(c)
SIZE DISTRIBUTION
SAMPLE NO. 022
FIR HOG FUEL

TABLE B6 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

FIR HOG FUEL (MB - WHITE PINE DIV.) SAMPLE 022A

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	43.6		
		2.5	6.2
		4.2	10.7
		8.4	18.1
		12.6	25.1
		16.8	30.7
		24.4	33.4
		27.0	43.6
48.1	60.8		
		4.2	17.3
		8.4	21.0
		16.8	38.4
		27.0	43.1
		33.7	48.1
		39.6	54.0
		48.1	60.8
59.9	74.8		
		4.2	9.1
		8.4	33.7
		16.8	35.7
		27.0	44.1
		43.8	61.7
		56.5	69.5
		59.9	74.8
81.8	98.1		
		4.2	17.0
		12.6	34.7
		27.0	46.3
		56.5	75.1
		59.9	78.7
		73.4	84.1
		81.8	98.1
98.7	117.8		
		4.2	17.8
		12.6	32.8
		27.0	51.8
		56.5	79.6
		73.4	102.3
		90.3	110.6
		98.7	117.8
115.6	137.6		
		4.2	14.4
		12.6	37.1
		27.0	56.2
		56.5	88.1
		81.8	111.7
		107.1	127.9
		115.6	137.6

TABLE B6 (b)

FIR HOG FUEL (MB - WHITE PINE DIV.) SAMPLE 022A (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	43.6	88.2	48.0	1.84	63.0	58.07	5.71	1.50
48.1	60.8	140.1	64.7	2.16	59.2	58.07	7.71	2.02
59.9	74.8	167.9	73.1	2.30	57.9	58.07	8.70	2.28
81.8	98.1	214.3	83.2	2.58	55.5	58.07	9.91	2.60
98.7	117.8	264.6	106.9	2.48	56.3	58.07	12.73	3.34
115.6	137.6	307.0	122.1	2.51	56.0	58.07	14.53	3.81

SHEAR INDEX (N) = 1.54

YIELD LOCUS	PERCENT FIT
1	98.2
2	99.6
3	98.8
4	99.8
5	99.8
6	99.8

TABLE B6 (c)

WALL FRICTION TEST RESULTS

FIR HOG FUEL (MB - WHITE PINE DIV.) SAMPLE 022A

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	41.6
67.3	37.3
58.8	33.0
50.3	28.7
41.9	24.2
33.5	19.9
25.0	15.6
16.5	11.0
8.0	6.0
3.7	3.0

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	47.3
67.3	42.7
58.8	37.6
50.3	32.6
41.9	27.5
33.5	22.3
25.0	17.1
16.5	11.6
8.0	5.8
3.7	2.4

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (ALONG "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	20.3
67.3	18.0
58.8	15.9
50.3	13.8
41.9	11.7
33.5	9.7
25.0	7.6
16.5	5.5
8.0	3.2
3.7	1.7

TABLE B6 (c) con't

WALL FRICTION TEST RESULTS

HOGFUEL SAMPLE

WALL MATERIAL - GLASS

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	59.6
150.4	51.2
122.4	42.5
94.3	33.7
66.2	24.6
52.2	18.6
38.2	14.4
24.1	9.8
10.1	5.1
4.9	3.2

TABLE B6 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

FIR HOG FUEL SAMPLE # 022-A

                         - TIME CONSOLIDATION RESULTS

CONSOLIDATION   YIELD POINT     <---------------FLOW PROPERTIES---------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC     UNCONFIN  EFFECT   INTERNAL COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N      YIELD     FRIC     FRIC ANG
                                 STRESS       STRESS    ANGLE    AT FREE
                                INST   TIME                       SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM      G/SQ CM    DEG       DEG     G/SQ CM

CONSOLIDATION PERIOD  20 HOURS

  48.1    60.5    48.1     64.9  140.1  147.7   73.5      61.0       58.1      8.76
  48.1    56.9    48.1     68.1  140.1  155.8   83.5      62.7       58.1      9.95
  81.8    91.7    81.8    104.6  214.3  237.1  108.2      59.0       58.1     12.90
  98.7   106.1    98.7    117.6  264.6  266.2  108.3      56.5       58.1     12.90

CONSOLIDATION PERIOD  165 HOURS

  81.8    97.5    81.8    109.8  214.3  249.8  123.1      60.7       58.1     14.68


                    SHEAR INDEX (N)    =    1.54

                    COHESION/ TENSILE
                            STRENGTH =    3.80
```

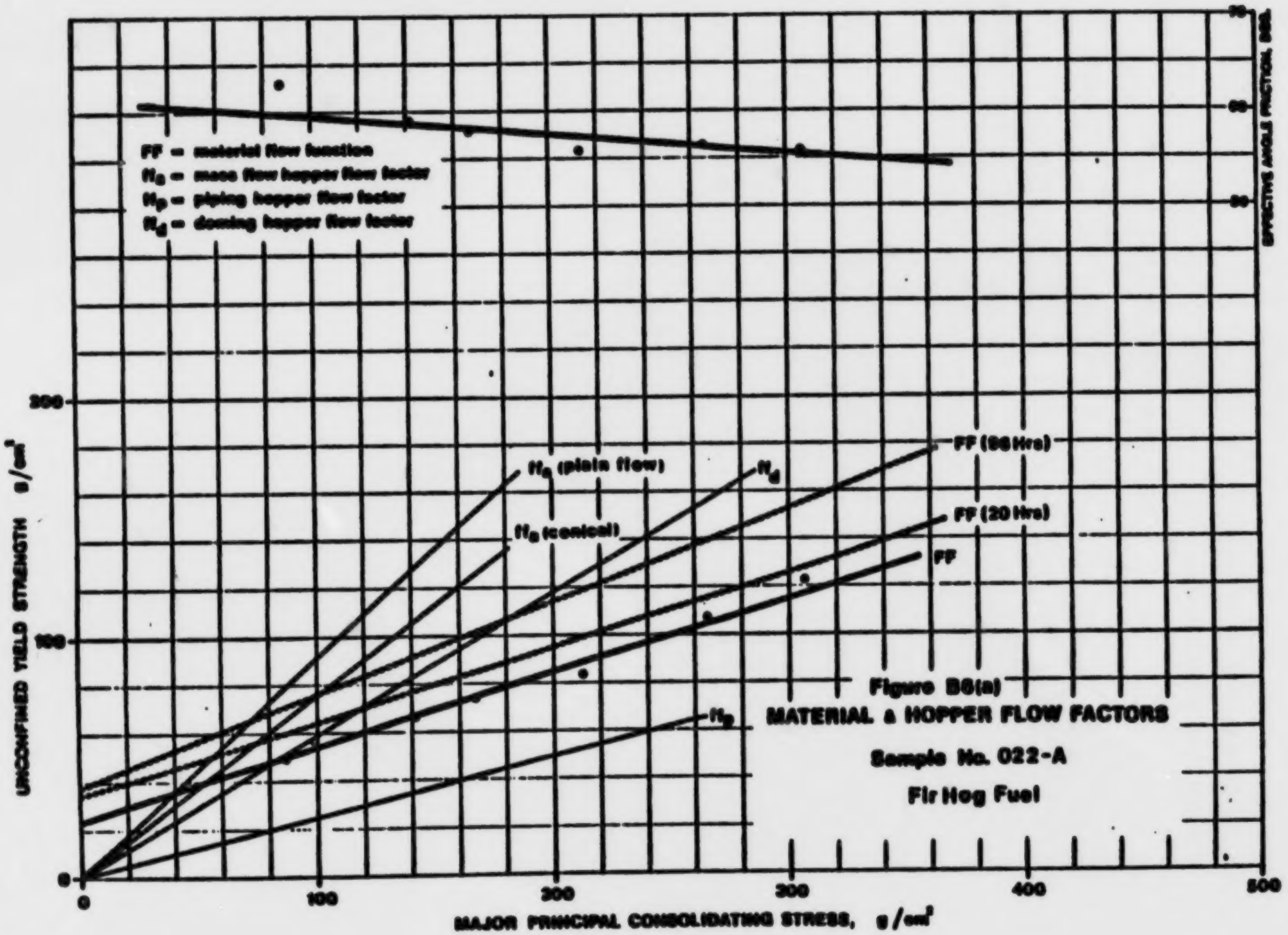

Figure B6(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 022-A
Fir Hog Fuel

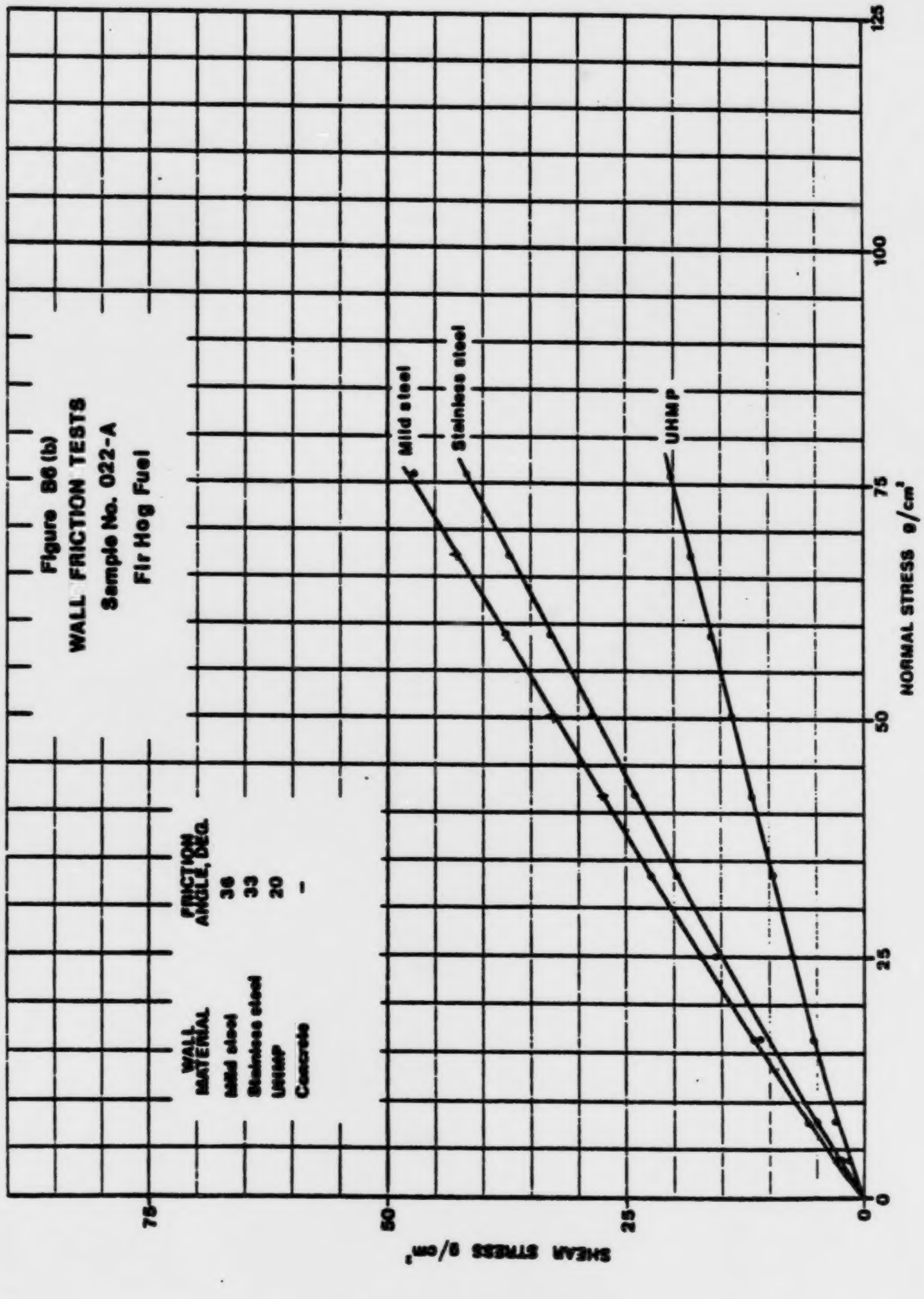

Figure B6 (b)
WALL FRICTION TESTS
Sample No. 022-A
Fir Hog Fuel

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	36
Stainless steel	33
UHMP	20
Concrete	-

TABLE B7 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK HOG FUEL (WONNOCK LUMBER) SAMLE 024

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	36.1		
		2.5	8.9
		4.2	14.3
		8.4	22.5
		12.6	22.5
		16.8	31.8
		24.4	33.1
		27.0	36.1
48.1	58.2		
		4.2	16.2
		8.4	19.3
		16.8	34.9
		27.0	43.1
		33.7	48.7
		39.6	57.2
		48.1	58.2
59.9	76.1		
		4.2	13.4
		8.4	21.2
		16.8	32.6
		27.0	46.2
		43.8	63.0
		56.5	71.8
		59.9	76.1
81.8	110.7		
		4.2	15.0
		12.6	31.8
		27.0	51.3
		56.5	76.8
		59.9	91.4
		73.4	100.5
		81.8	110.7
98.7	117.6		
		4.2	15.7
		12.6	38.8
		27.0	73.9
		56.5	96.5
		73.4	101.1
		90.3	111.2
		98.7	117.6
115.6	140.4		
		4.2	18.8
		12.6	30.1
		27.0	58.8
		56.5	79.5
		81.8	104.6
		107.1	129.5
		115.6	140.4

TABLE B7 (b)

HEMLOCK HOG FUEL (WONNOCK LUMBER) SAMLE 024 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	36.1	83.7	48.1	1.74	62.9	56.67	5.88	1.50
48.1	58.2	135.2	68.0	1.99	59.4	56.67	8.30	2.12
59.9	76.1	164.5	80.0	2.06	58.5	56.67	9.76	2.49
81.8	110.7	233.0	119.3	1.95	59.8	56.67	14.56	3.71
98.7	117.6	273.9	135.1	2.03	58.9	56.67	16.49	4.20
115.6	140.4	295.9	128.6	2.30	55.8	56.67	15.70	4.00

SHEAR INDEX (N) = 1.59

YIELD LOCUS	PERCENT FIT
1	99.0
2	99.7
3	99.6
4	99.3
5	98.8
6	99.5

TABLE B7 (c)

WALL FRICTION TEST RESULTS

HEMLOCK HOG FUEL (WONNOCK LUMBER) SAMPLE 024

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	39.9
68.1	35.5
59.6	31.5
51.2	27.2
42.8	23.0
34.4	18.9
25.9	14.8
17.4	10.5
8.9	6.0
4.5	3.5

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	43.9
68.1	39.4
59.6	34.8
51.2	30.0
42.8	25.3
34.4	20.8
25.9	16.1
17.4	11.3
8.9	6.3
4.5	3.4

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	23.3
68.1	20.8
59.6	18.3
51.2	16.1
42.8	13.7
34.4	11.2
25.9	8.9
17.4	6.5
8.9	3.9
4.5	2.3

TABLE B7 (c) con't

WALL MATERIAL - GALVANISED STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.6	40.1
68.1	36.7
59.6	32.8
51.2	28.5
42.8	24.1
34.4	19.7
25.9	15.4
17.4	11.0
8.9	6.3
4.5	3.5

TABLE B7 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

HEMLOCK HOG FUEL SAMPLE # 024

                                  - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT      <---------------FLOW PROPERTIES---------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC       UNCONFIN  EFFECT  INTERNAL  COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N        YIELD     FRIC    FRIC ANG
                                  STRESS        STRESS    ANGLE   AT FREE
                                 INST   TIME                       SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM        G/SQ CM    DEG      DEG     G/SQ CM

CONSOLIDATION PERIOD  20 HOURS

  48.1    62.3    48.1    70.1  135.2  158.7    97.3      64.8      56.8    11.83
  48.1    52.9    48.1    61.4  135.2  137.4    69.9      59.8      56.8     8.50
  81.8    93.6    81.8   107.3  233.0  240.5   127.2      60.8      56.8    15.46

CONSOLIDATION PERIOD  92 HOURS

  98.7   118.6    98.7   141.6  273.9  319.8   191.7      64.2      56.8    23.31

                    SHEAR INDEX (N)   =    1.59

                    COHESION/ TENSILE
                            STRENGTH =    3.93
```

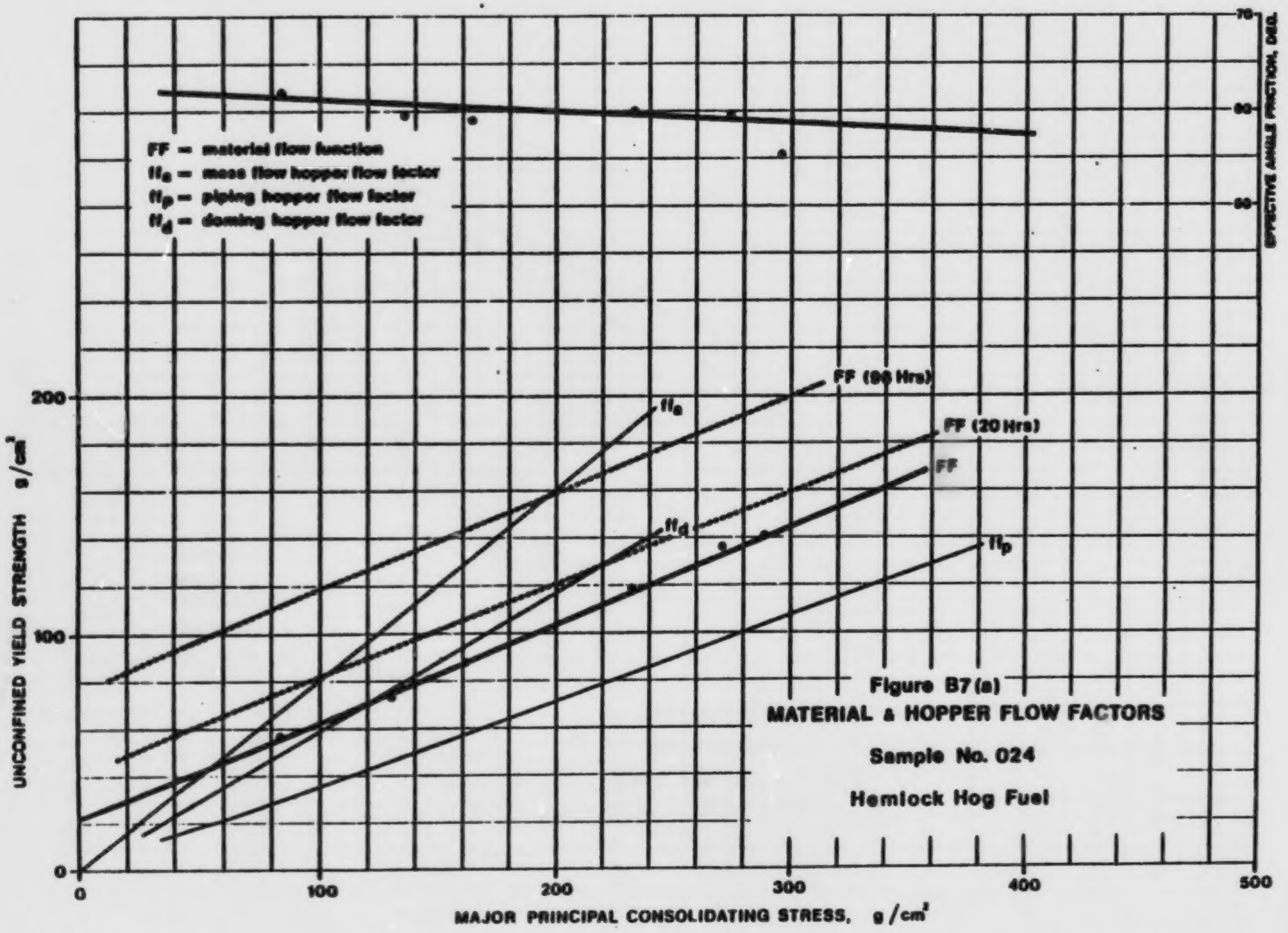

Figure B7(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 024
Hemlock Hog Fuel

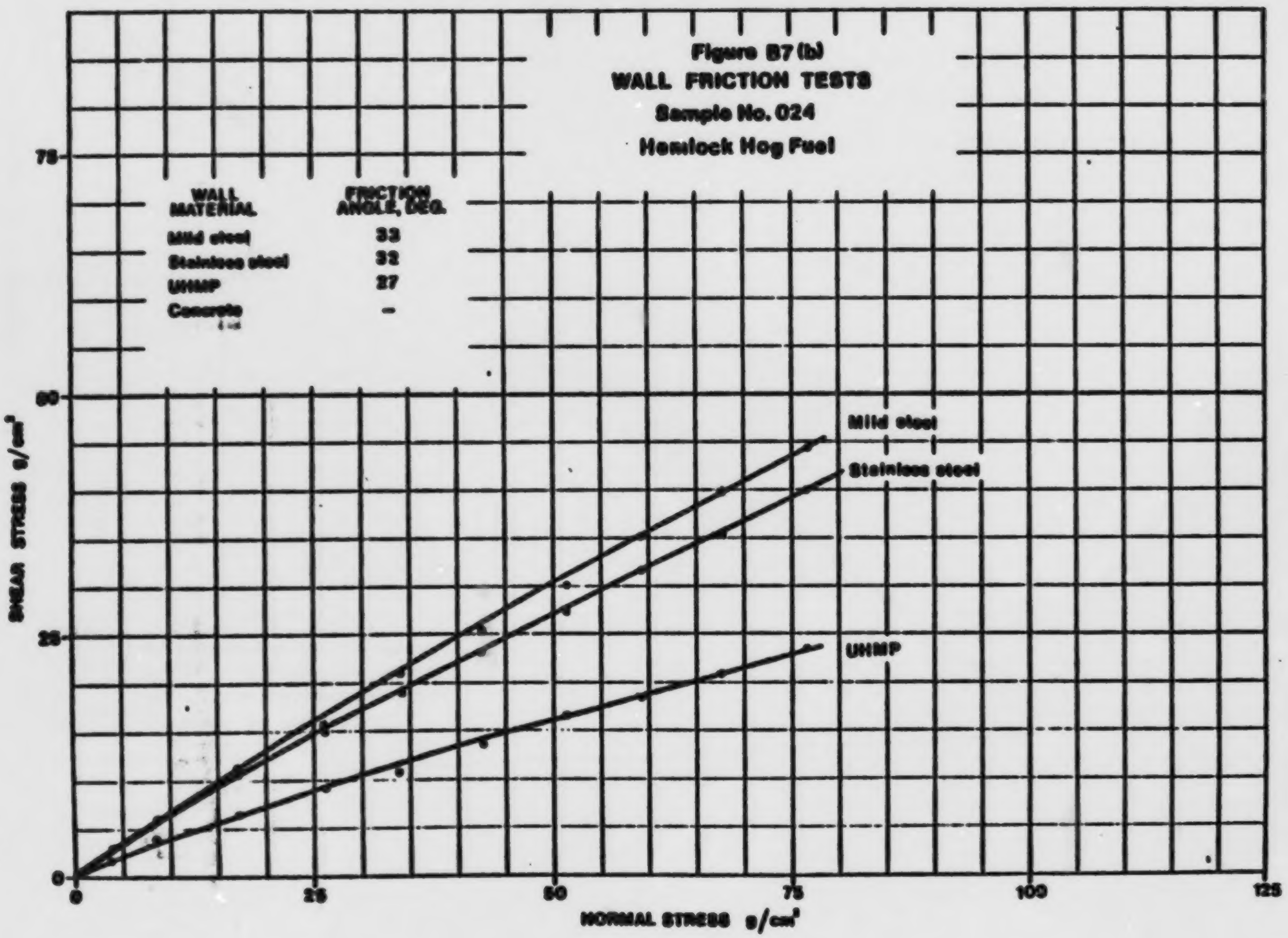

Figure B7 (b)
WALL FRICTION TESTS
Sample No. 024
Hemlock Hog Fuel

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	33
Stainless steel	32
UHMP	27
Concrete	–

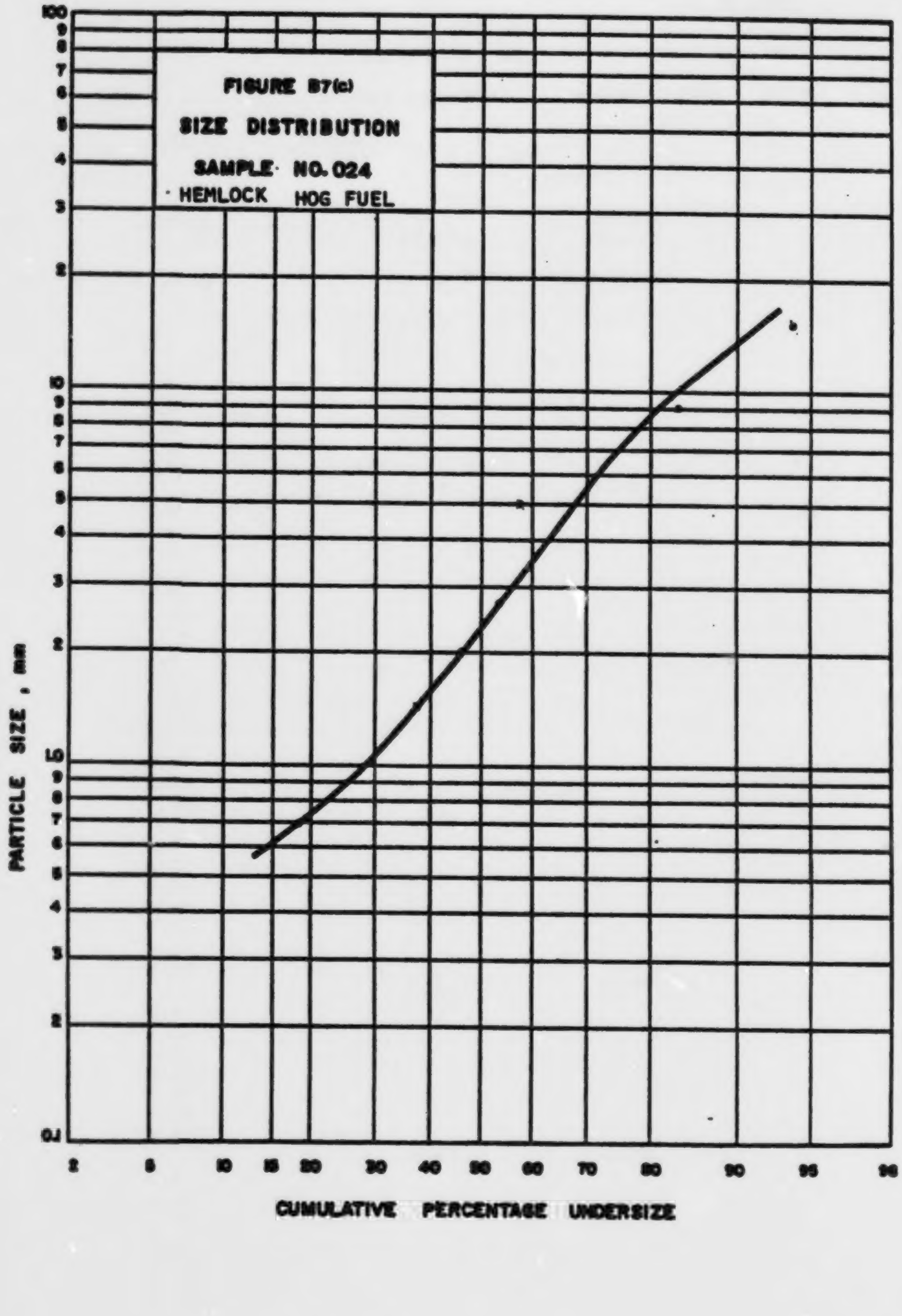
FIGURE B7(c)
SIZE DISTRIBUTION
SAMPLE NO. 024
HEMLOCK HOG FUEL
PARTICLE SIZE, mm
100
9
8
7
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1.0
9
8
7
6
5
4
3
2
0.1
2
5
10
15
20
30
40
50
60
70
80
90
95
98
CUMULATIVE PERCENTAGE UNDERSIZE

TABLE B8 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

PINE / SPRUCE HOG FUEL (INTERCONTINENTAL PULP) SAMPLE 027

.- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	36.1		
		2.5	8.1
		4.2	12.5
		8.4	16.5
		12.6	21.2
		16.8	24.8
		24.4	30.5
		27.0	36.1
48.1	59.2		
		4.2	10.7
		8.4	19.3
		16.8	30.5
		27.0	44.1
		33.7	45.4
		39.6	54.8
		48.1	59.2
59.9	72.4		
		4.2	15.6
		8.4	17.8
		16.8	36.2
		27.0	53.7
		43.8	62.4
		56.5	64.1
		59.9	72.4
81.8	94.2		
		4.2	14.0
		12.6	24.8
		27.0	47.5
		56.5	78.0
		59.9	83.9
		73.4	90.2
		81.8	94.2
98.7	112.2		
		4.2	13.7
		12.6	24.8
		27.0	53.4
		56.5	95.3
		73.4	102.1
		90.3	111.2
		98.7	112.2
115.6	133.5		
		4.2	10.3
		12.6	31.5
		27.0	66.1
		56.5	103.1
		81.8	122.3
		107.1	132.6
		115.6	133.5

TABLE B8 (b)

PINE / SPRUCE HOG FUEL (INTERCONTINENTAL PULP) SAMPLE 027 (CONT)

.- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	36.1	76.8	35.1	2.19	58.5	57.39	4.29	1.16
48.1	59.2	133.4	58.4	2.29	57.6	57.39	7.13	1.94
59.9	72.4	164.7	71.1	2.32	57.3	57.39	8.69	2.36
81.8	94.2	216.4	87.4	2.48	55.9	57.39	10.69	2.90
98.7	112.2	265.8	110.7	2.40	56.5	57.39	13.53	3.67
115.6	133.5	319.5	139.0	2.30	57.5	57.39	16.99	4.61

SHEAR INDEX (N) = 1.54

YIELD LOCUS	PERCENT FIT
1	99.7
2	99.5
3	98.8
4	99.6
5	99.0
6	98.7

TABLE B8 (c)

WALL FRICTION TEST RESULTS

PINE / SPRUCE HOG FUEL (INTERCONTINENTAL PULP) SAMPLE #027

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.1	39.6
66.6	35.6
58.1	31.6
49.7	27.4
41.3	23.3
32.9	19.1
24.4	14.8
15.9	10.3
7.4	5.6
3.0	2.2

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.1	44.7
66.6	40.5
58.1	35.6
49.7	30.9
41.3	26.1
32.9	21.3
24.4	16.4
15.9	11.5
7.4	5.7
3.0	2.3

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.1	20.7
66.6	18.5
58.1	16.3
49.7	14.2
41.3	12.0
32.9	9.9
24.4	7.7
15.9	5.4
7.4	3.0
3.0	1.3

TABLE B8 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

PINE/SPRUCE HOG FUEL SAMPLE # 027

                    - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT     <---------------FLOW PROPERTIES--------------->

NORMAL  SHEAR    NORMAL  SHEAR    MAJ PRINC      UNCONFIN  EFFECT  INTERNAL  COHESION
STRESS  STRESS   STRESS  STRESS   CONSOL'N       YIELD     FRIC    FRIC ANG
                                   STRESS        STRESS    ANGLE   AT FREE
                                 INST    TIME                       SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM         G/SQ CM    DEG      DEG     G/SQ CM

CONSOLIDATION PERIOD  20 HOURS

  48.1    55.8    48.1    63.1   133.4   143.2    69.8     60.1     57.5      8.51
  59.9    63.3    59.9    71.5   164.7   161.6    67.5     56.6     57.5      8.23
  81.8    88.4    81.8   103.8   216.4   235.0   108.5     58.8     57.5     13.22
  98.7   101.8    98.7   113.7   265.8   257.1   101.0     55.3     57.5     12.32
CONSOLIDATION PERIOD  30 HOURS

  59.9    69.6    59.9    79.9   164.7   181.3    90.5     60.6     57.5     11.03
CONSOLIDATION PERIOD  68 HOURS

  48.1    60.0    48.1    65.5   133.4   149.0    76.9     61.4     57.5      9.38
CONSOLIDATION PERIOD  71 HOURS

  81.8    97.8    81.8   106.6   216.4   241.5   116.2     59.8     57.5     14.17


                    SHEAR INDEX (N)    =   1.54

                    COHESION/ TENSILE
                            STRENGTH =   3.70
```

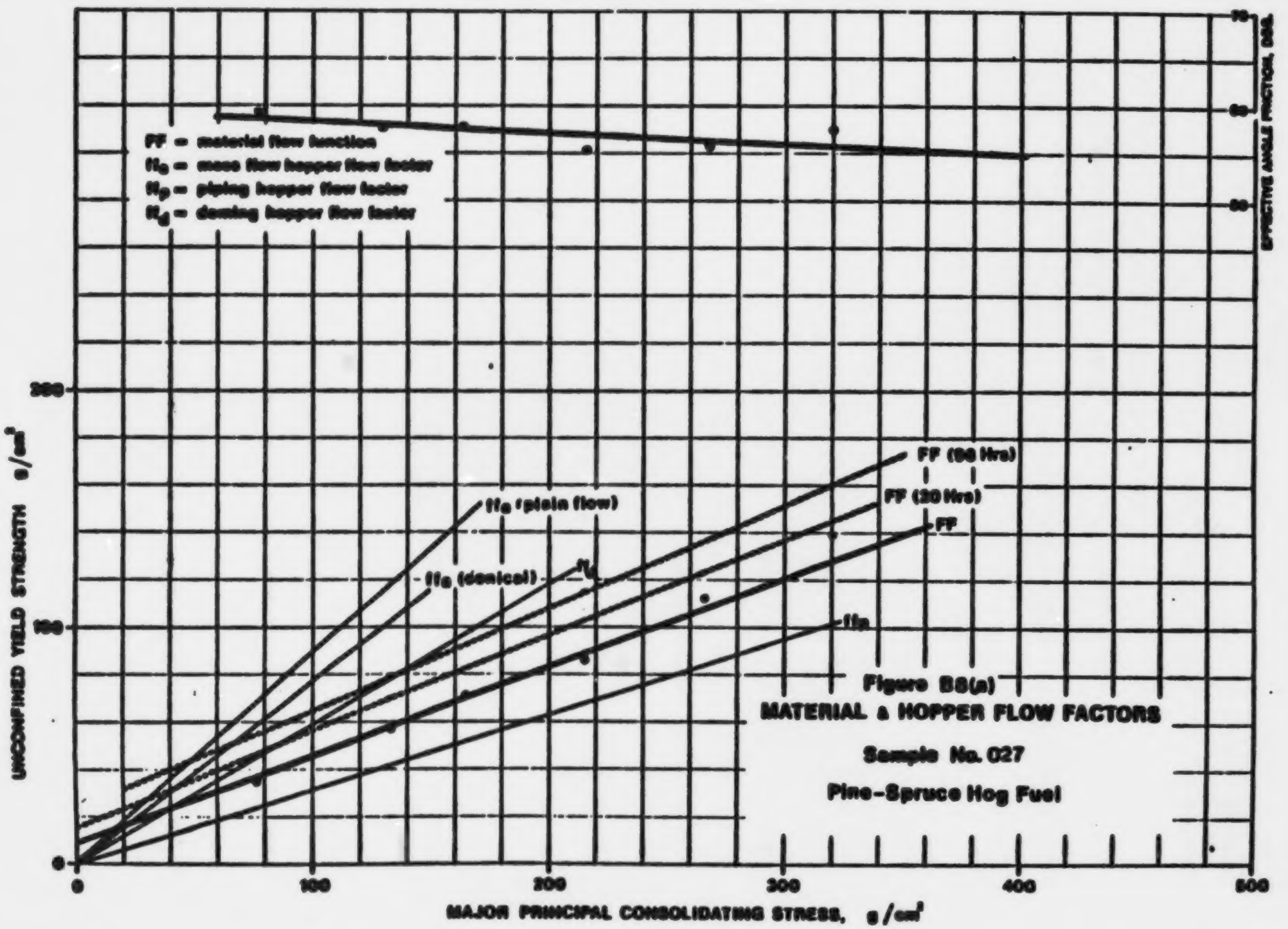

Figure B8(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 027
Pine-Spruce Hog Fuel

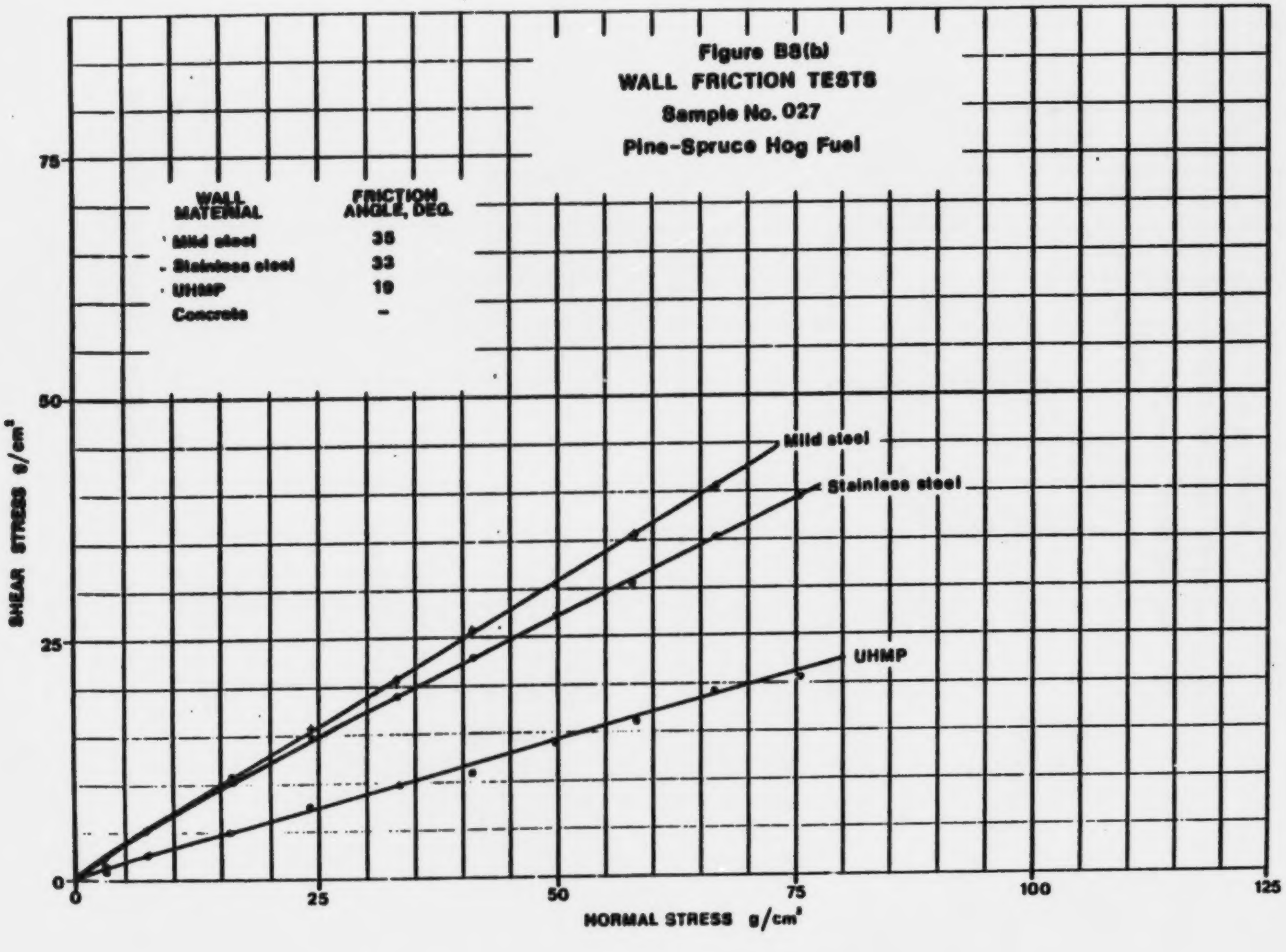

Figure B8(b)
WALL FRICTION TESTS
Sample No. 027
Pine-Spruce Hog Fuel

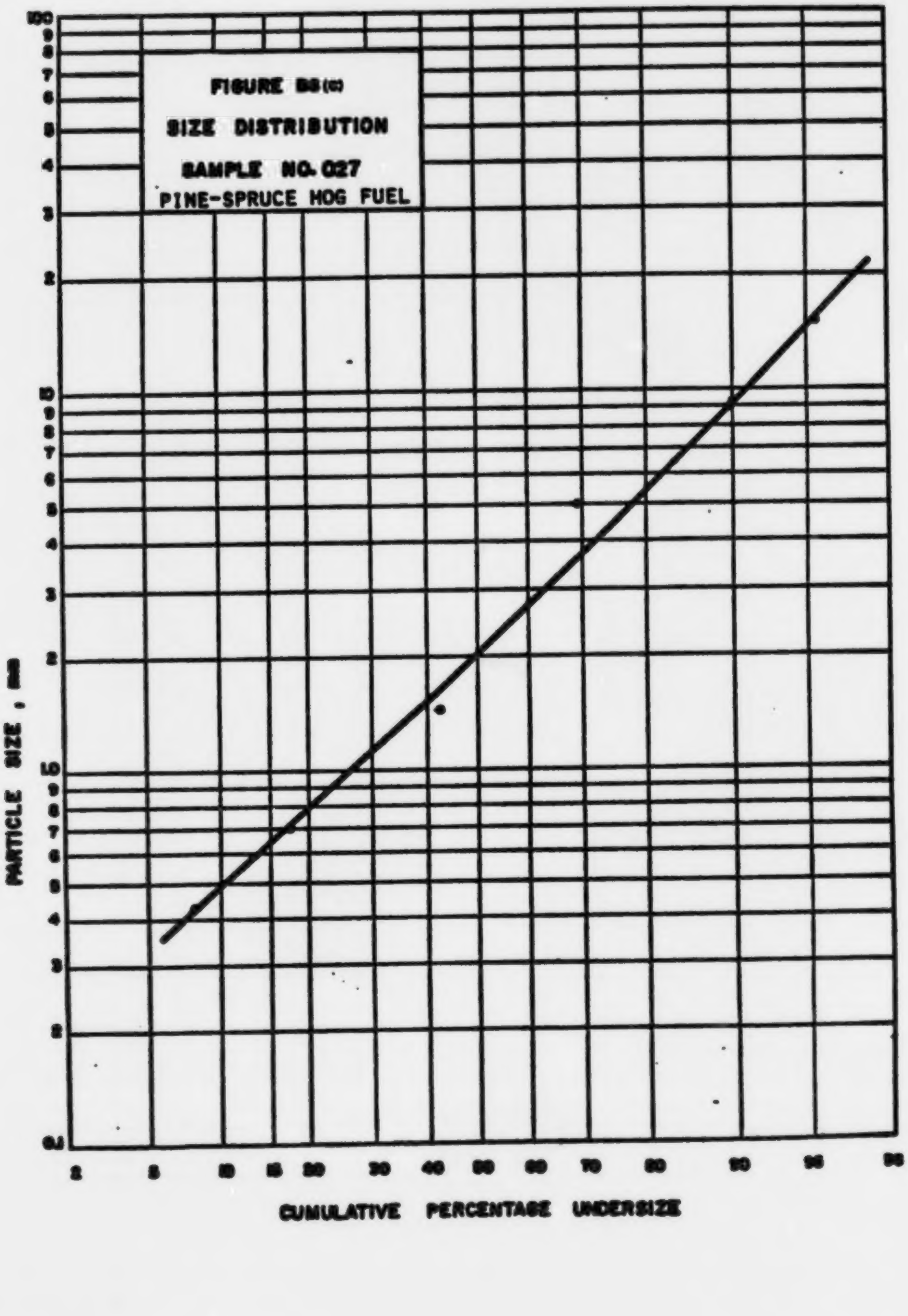

FIGURE B8(c)

SIZE DISTRIBUTION

SAMPLE NO. 027

PINE-SPRUCE HOG FUEL

TABLE B9 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR HOG FUEL (MB - CANADIAN WHITE PINE DIV.) SAMPLE 030

.- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	35.3		
		2.5	13.2
		4.2	16.6
		8.4	21.7
		12.6	22.7
		16.8	28.4
		24.4	31.7
		27.0	35.3
48.1	58.7		
		4.2	12.2
		8.4	24.8
		16.8	33.8
		27.0	41.7
		33.7	47.4
		39.6	52.7
		48.1	58.7
59.9	82.2		
		4.2	12.5
		8.4	23.3
		16.8	30.1
		27.0	49.9
		43.8	72.0
		56.5	76.1
		59.9	82.2
81.8	106.7		
		4.2	27.8
		12.6	51.9
		27.0	62.3
		56.5	83.0
		59.9	95.7
		73.4	101.7
		81.8	106.7
98.7	137.3		
		4.2	17.5
		12.6	29.0
		27.0	69.8
		56.5	108.0
		73.4	123.6
		90.3	140.4
		98.7	137.3
115.6	159.1		
		4.2	21.5
		12.6	45.0
		27.0	67.9
		56.5	104.0
		81.8	127.9
		107.1	150.4
		115.6	159.1

TABLE B9 (b)

CEDAR HOG FUEL (MB - CANADIAN WHITE PINE DIV.) SAMPLE 030 (CONT.)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	35.3	80.2	48.7	1.65	63.0	55.74	5.92	1.39
48.1	58.7	128.9	68.4	1.88	59.1	55.74	8.32	1.96
59.9	82.2	172.1	100.2	1.72	61.8	55.74	12.19	2.87
81.8	106.7	242.9	147.2	1.65	63.0	55.74	17.90	4.21
98.7	137.3	308.3	198.2	1.56	64.8	55.74	24.11	5.67
115.6	159.1	340.8	204.9	1.66	62.7	55.74	24.91	5.86

SHEAR INDEX (N) = 1.66

YIELD LOCUS	PERCENT FIT
1	99.1
2	99.7
3	98.6
4	99.4
5	98.5
6	99.6

TABLE B9 (c)

WALL FRICTION TEST RESULTS

CEDAR HOG FUEL SAMPLE #030 (C. WHITE PINE)

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	38.7
67.0	34.8
58.5	30.8
50.0	26.9
41.6	23.0
33.2	18.9
24.7	14.9
16.2	10.7
7.7	5.8
3.4	2.7

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	44.1
67.0	39.6
58.5	34.8
50.0	30.3
41.6	25.6
33.2	21.0
24.7	16.3
16.2	11.4
7.7	6.2
3.4	2.8

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	21.5
67.0	19.1
58.5	17.0
50.0	14.9
41.6	12.7
33.2	10.8
24.7	8.7
16.2	6.3
7.7	3.7
3.4	1.9

TABLE B9 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

CEDAR HOG FUEL SAMPLE # 030

                                - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT      <---------------FLOW PROPERTIES------------------>

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC        UNCONFIN  EFFECT  INTERNAL COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N         YIELD     FRIC    FRIC ANG
                                  STRESS         STRESS    ANGLE   AT FREE
                                INST    TIME                        SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM         G/SQ CM    DEG      DEG     G/SQ CM


CONSOLIDATION PERIOD  20 HOURS

  59.9   76.1    59.9    86.1  172.1  191.3  125.5      65.6       55.9     15.22
  81.8  104.0    81.8   118.1  242.9  262.4  172.9      65.7       55.9     20.95
  98.7  133.2    98.7   142.3  308.3  316.2  208.0      65.6       55.9     25.22

CONSOLIDATION PERIOD  40 HOURS

  48.1   55.7    48.1    64.0  128.9  141.4   84.3      62.6       55.9     10.22

CONSOLIDATION PERIOD  66 HOURS

  48.1   57.2    48.1    66.6  128.9  147.6   92.6      64.1       55.9     11.22


                       SHEAR INDEX (N)    =   1.66

                       COHESION/ TENSILE
                               STRENGTH =   4.26
```

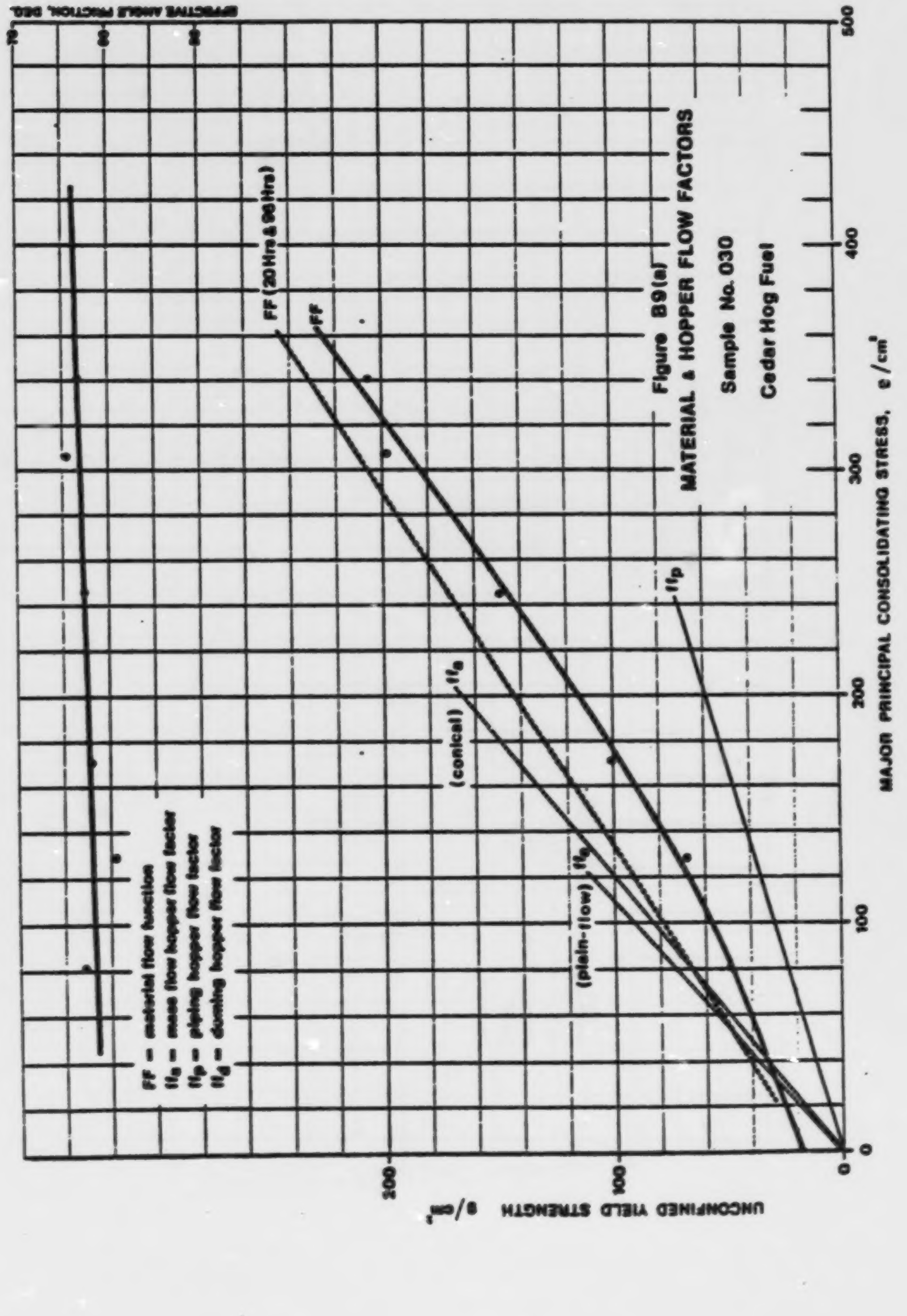

Figure B9(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 030

Cedar Hog Fuel

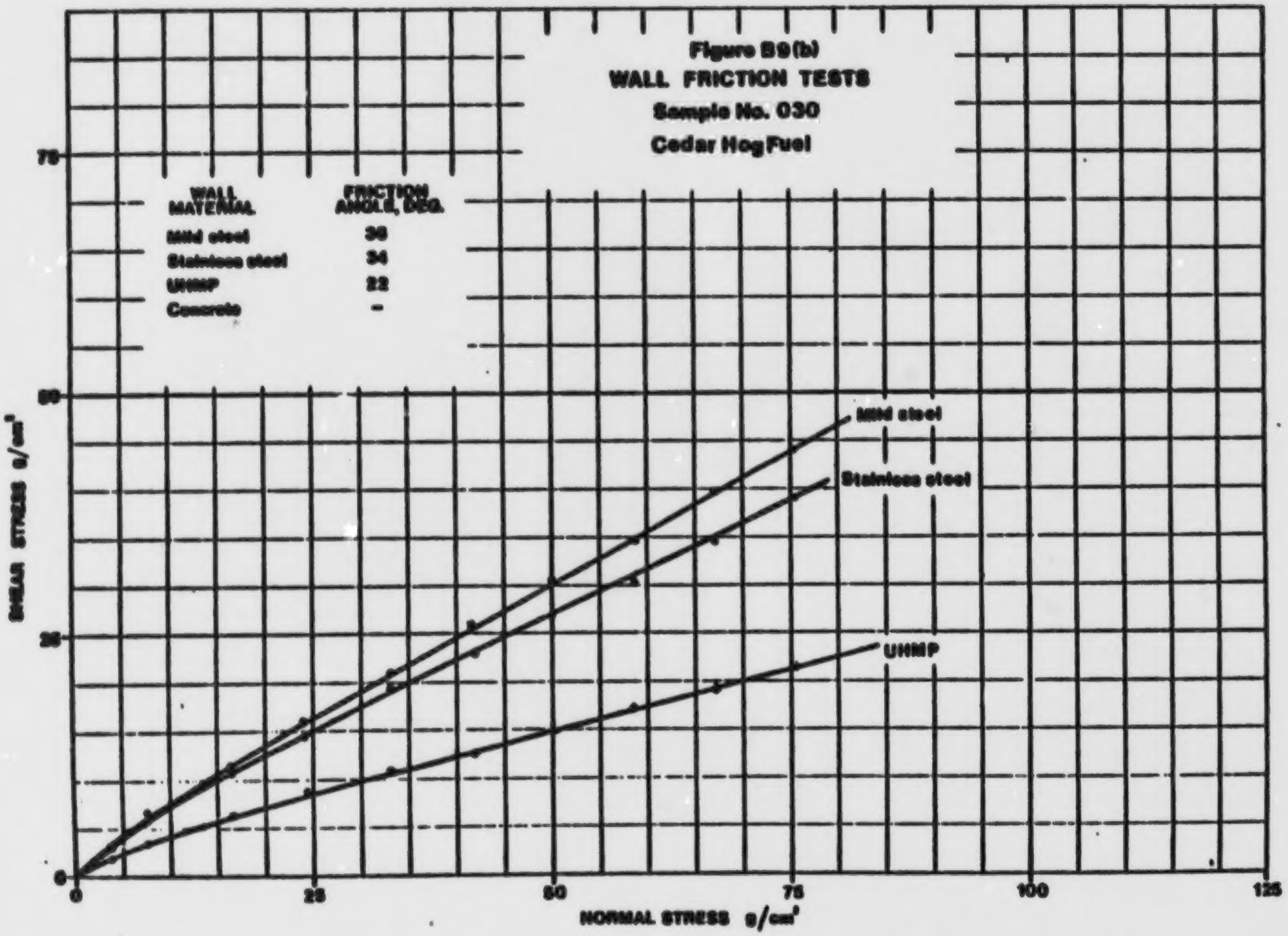

Figure B9(b)
WALL FRICTION TESTS
Sample No. 030
Cedar Hog Fuel

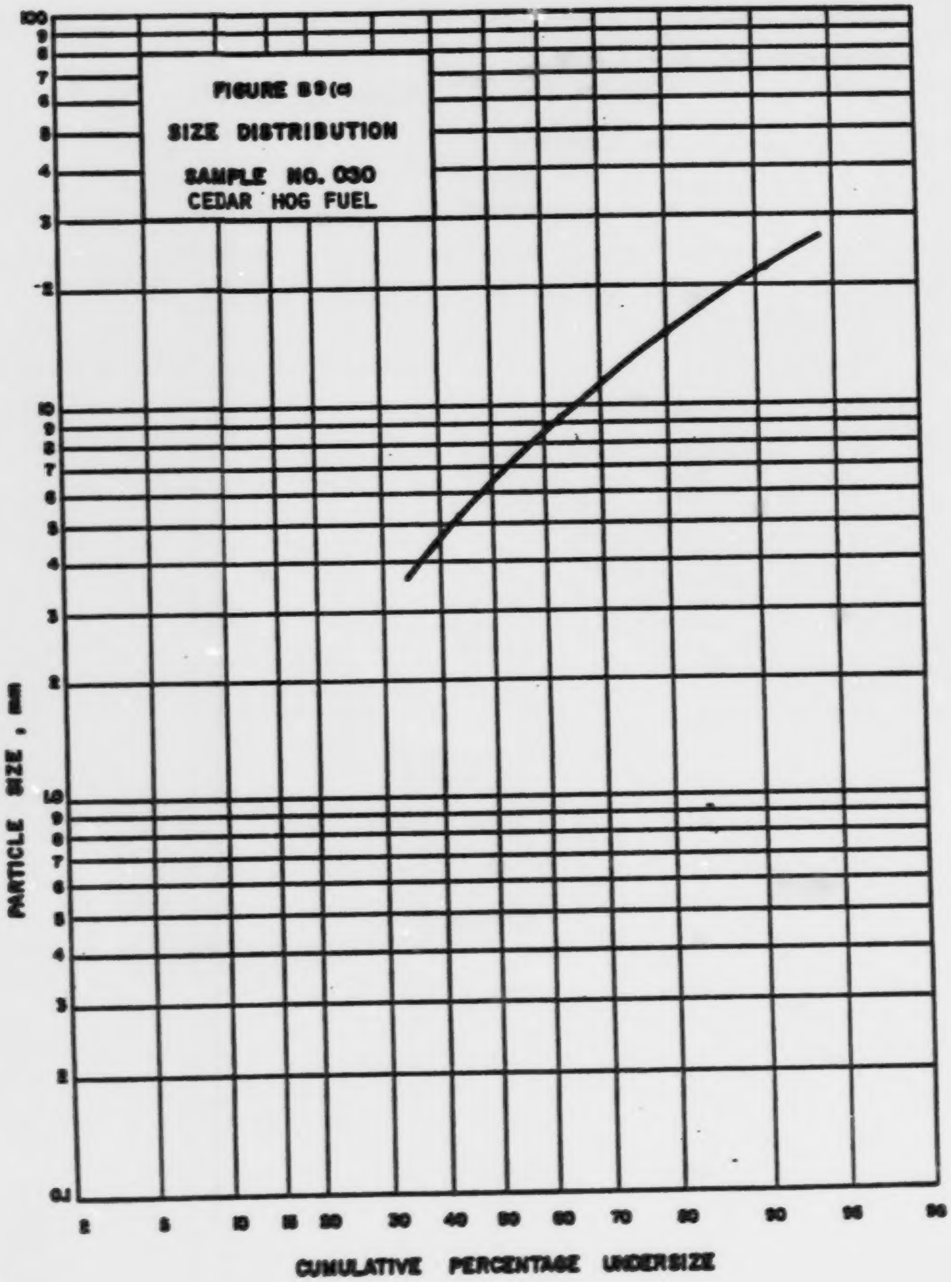

FIGURE B9(a)
SIZE DISTRIBUTION
SAMPLE NO. 030
CEDAR HOG FUEL

TABLE B10 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR HOG FUEL SAMPLE #031

– SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	35.1		
		2.5	5.2
		4.2	11.1
		8.4	16.0
		12.6	22.9
		16.8	28.6
		24.4	31.6
		27.0	35.1
48.1	63.6		
		4.2	11.7
		8.4	22.5
		16.8	29.6
		27.0	38.8
		33.7	48.9
		39.5	50.4
		48.1	63.6
59.9	68.0		
		4.2	14.6
		8.4	21.7
		16.8	30.1
		27.0	52.5
		43.8	63.0
		56.5	66.9
		59.9	68.0
81.8	106.1		
		4.2	14.0
		12.6	42.7
		27.0	49.5
		56.5	73.6
		59.9	77.5
		73.4	96.1
		81.8	106.1
98.7	113.1		
		4.2	16.5
		12.6	26.8
		27.0	53.1
		56.5	90.1
		73.4	97.3
		90.3	105.0
		98.7	113.1
115.6	130.4		
		4.2	14.0
		12.6	27.9
		27.0	54.5
		56.5	85.5
		81.8	111.6
		107.1	124.2
		115.6	130.4

TABLE B10 (b)

CEDAR HOG FUEL SAMPLE #031 (CONT)

.- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	35.1	79.2	35.2	2.25	58.9	58.02	4.26	1.18
48.1	63.6	135.5	56.4	2.40	57.5	58.02	6.82	1.88
59.9	68.0	164.1	65.1	2.52	56.5	58.02	7.87	2.17
81.8	106.1	228.9	94.1	2.43	57.2	58.02	11.38	3.14
98.7	113.1	261.8	98.0	2.67	55.4	58.02	11.85	3.27
115.6	130.4	299.2	107.1	2.79	54.5	58.02	12.95	3.57

SHEAR INDEX (N) = 1.51

YIELD LOCUS	PERCENT FIT
1	99.1
2	99.5
3	99.0
4	99.2
5	99.5
6	99.6

TABLE B10 (c)

WALL FRICTION TEST RESULTS

CEDAR HOG FUEL (MB - CAN. WHITE PINE DIV.) SAMPLE 031

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.0	39.6
66.5	35.4
58.1	31.3
49.6	27.0
41.2	22.9
32.8	18.6
24.3	14.3
15.8	9.7
7.3	4.7
2.9	1.7

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.0	44.7
66.5	39.9
58.1	35.1
49.6	30.3
41.2	25.3
32.8	20.3
24.3	15.2
15.8	10.1
7.3	4.7
2.9	1.7

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.0	20.1
66.5	16.2
58.1	14.3
49.6	12.5
41.2	10.7
32.8	8.8
24.3	6.8
15.8	4.8
7.3	2.5
2.9	1.1

TABLE B10 (c) con't

WALL FRICTION TEST RESULTS

CEDAR HOG FUEL SAMPLE # 031

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.1	117.0
150.1	98.0
122.0	81.7
93.9	60.8
65.9	43.4
51.8	33.3
37.8	24.3
23.8	15.2
9.7	6.0
4.5	2.8

WALL MATERIAL - GLASS

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.1	63.6
150.1	55.4
122.0	46.7
93.9	36.9
65.9	26.9
51.8	22.1
37.8	16.8
23.8	11.9
9.7	6.2
4.5	3.2

TABLE B10 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

CEDAR HOG FUEL SAMPLE # 031

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<——FLOW PROPERTIES——>					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS INST	MAJ PRINC CONSOL'N STRESS TIME	UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20 HOURS									
27.0	34.0	27.0	34.2	79.2	78.0	33.5	58.3	58.1	4.06
81.8	95.8	81.8	106.3	228.9	242.9	108.8	59.2	58.1	13.17
98.7	114.2	98.7	125.7	261.8	286.9	124.3	58.5	58.1	15.04
CONSOLIDATION PERIOD 40 HOURS									
48.1	58.7	48.1	67.4	135.5	155.0	78.6	61.9	58.1	9.50
CONSOLIDATION PERIOD 65 HOURS									
48.1	56.5	48.1	66.6	135.5	153.1	76.2	61.5	58.1	9.22
CONSOLIDATION PERIOD 71 HOURS									
81.8	88.4	81.8	110.1	228.9	252.3	119.8	60.4	58.1	14.49

SHEAR INDEX (N) = 1.51

COHESION/ TENSILE
STRENGTH = 3.61

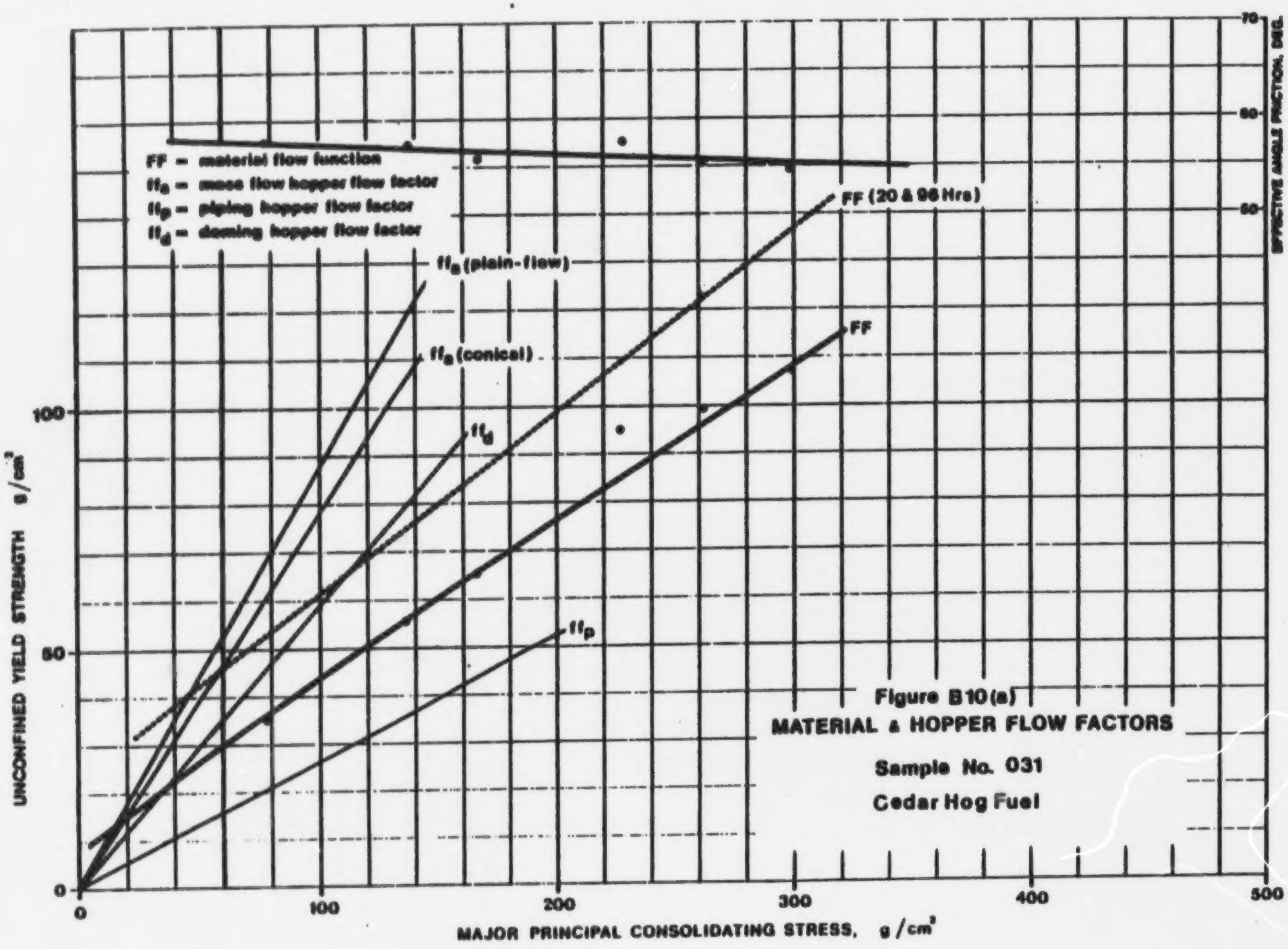

Figure B10(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 031
Cedar Hog Fuel

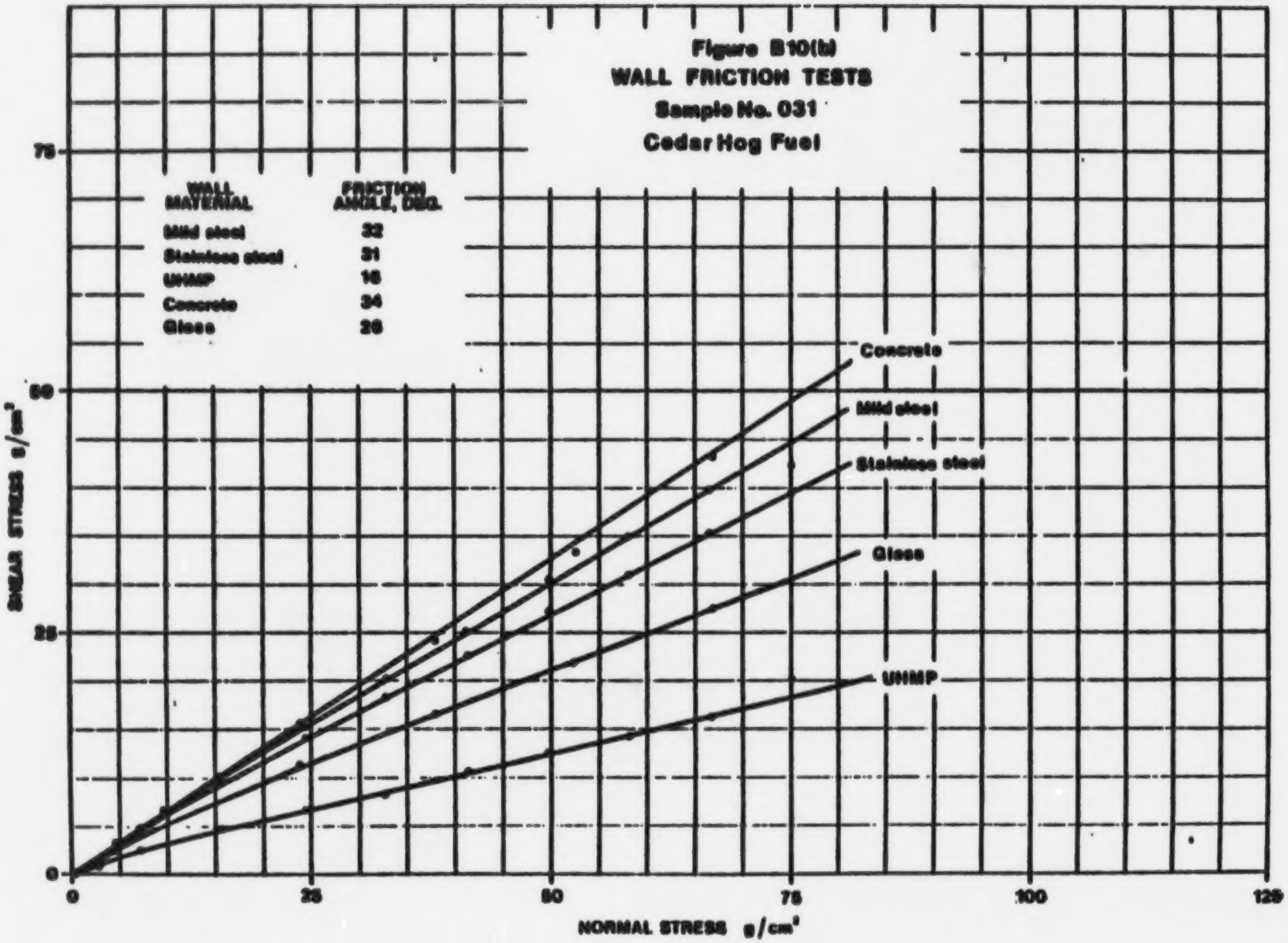

Figure B10(b)
WALL FRICTION TESTS
Sample No. 031
Cedar Hog Fuel

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	32
Stainless steel	31
UHMP	16
Concrete	34
Glass	26

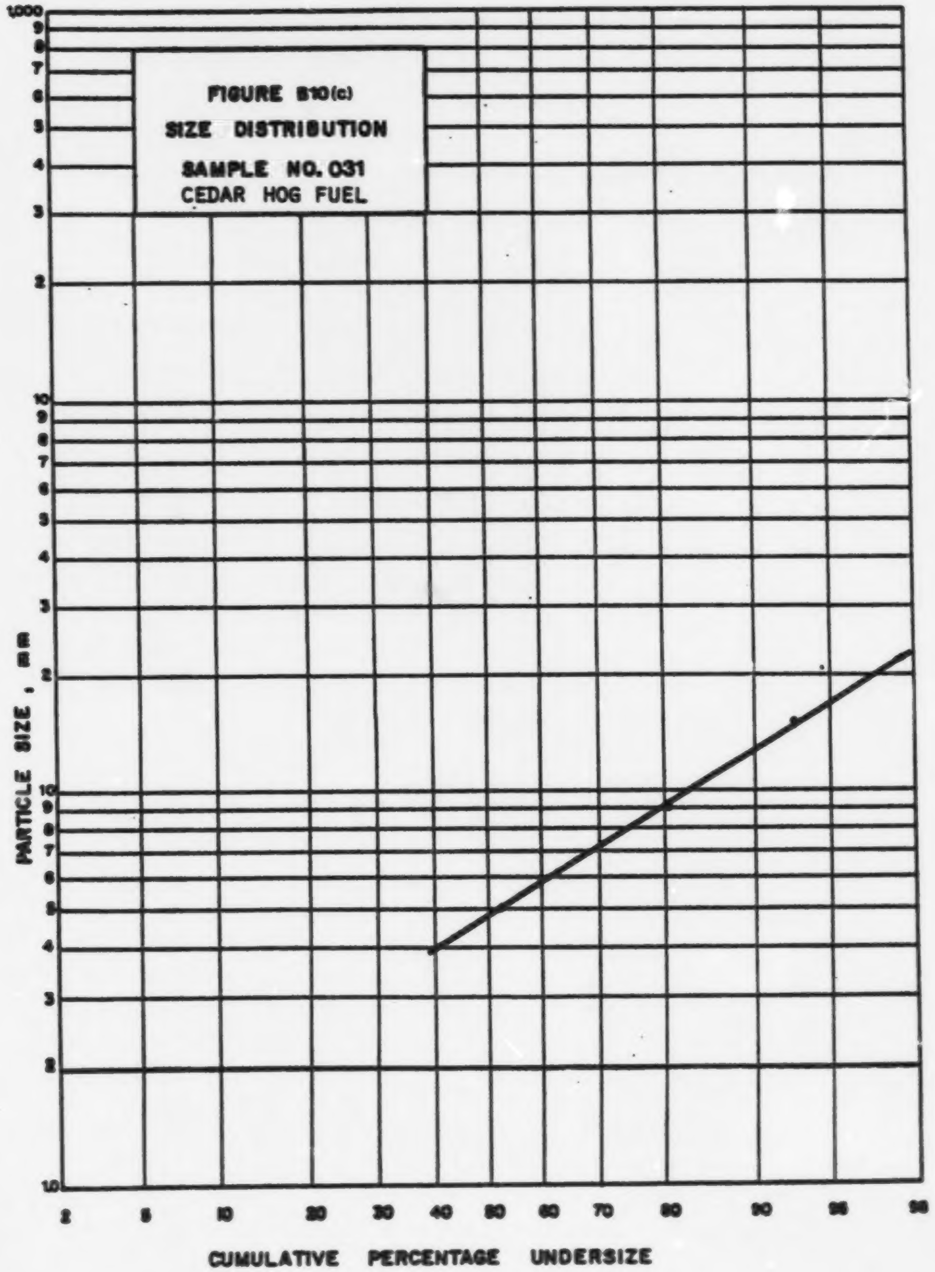

FIGURE B10(c)
SIZE DISTRIBUTION
SAMPLE NO. 031
CEDAR HOG FUEL

TABLE B11 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR HOG FUEL (C.W. PINE) SAMPLE # 031-C

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	56.8		
		2.5	6.7
		4.2	9.0
		8.4	19.7
		12.6	22.1
		16.8	28.9
		24.4	38.0
		27.0	56.8
48.1	63.9		
		4.2	12.0
		8.4	26.4
		16.8	32.9
		27.0	45.2
		33.7	66.1
		39.6	66.3
		48.1	63.9
59.9	87.4		
		4.2	20.0
		8.4	22.0
		16.8	34.1
		27.0	46.2
		43.8	59.9
		56.5	75.1
		59.9	87.4
81.8	135.1		
		4.2	17.8
		12.6	46.7
		27.0	62.0
		56.5	98.1
		59.9	119.6
		73.4	121.7
		81.8	135.1
98.7	140.4		
		4.2	34.0
		12.6	39.2
		27.0	65.0
		56.5	100.7
		73.4	116.7
		90.3	131.4
		98.7	140.4
115.6	168.2		
		4.2	17.5
		12.6	57.7
		27.0	94.2
		56.5	119.8
		81.8	137.3
		107.1	143.5
		115.6	168.2

TABLE B11 (b)

CEDAR HOG FUEL (C.W. PINE) SAMPLE # 031-C (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	56.8	108.4	46.6	2.33	64.8	64.76	4.44	1.01
48.1	63.9	171.2	61.9	2.77	61.8	64.77	5.90	1.34
59.9	87.4	190.3	57.3	3.32	58.8	64.76	5.47	1.24
81.8	135.1	329.4	141.7	2.33	64.8	64.76	13.52	3.07
98.7	140.4	342.4	118.8	2.88	61.1	64.76	11.34	2.58
115.6	168.2	414.7	151.5	2.74	62.0	64.77	14.46	3.28

SHEAR INDEX (N) = 1.45

YIELD LOCUS	PERCENT FIT
1	95.2
2	98.3
3	99.3
4	99.5
5	99.6
6	97.7

TABLE B11 (d)

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COMPUTER ANALYSIS OF STORAGE AT REST

CEDAR HOG FUEL SAMPLE # 031-C

                                  - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT      <----------------FLOW PROPERTIES----------------->

NORMAL  SHEAR    NORMAL  SHEAR    MAJ PRINC      UNCONFIN  EFFECT  INTERNAL COHESION
STRESS  STRESS   STRESS  STRESS   CONSOL'N       YIELD     FRIC    FRIC ANG
                                   STRESS        STRESS    ANGLE   AT FREE
                                 INST    TIME                       SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM         G/SQ CM    DEG      DEG     G/SQ CM


CONSOLIDATION PERIOD  20 HOURS

  27.0    38.7    27.0    47.4  108.4  119.1    58.3     67.0       64.7      5.58
 115.6   137.9   115.6   157.2  414.7  371.3   115.4     59.1       64.7     11.04

CONSOLIDATION PERIOD  41 HOURS

  48.1    54.1    48.1    84.9  171.2  213.3   105.1     67.1       64.7     10.06

CONSOLIDATION PERIOD  68 HOURS

  98.7   119.8    98.7   145.1  342.4  347.4   124.8     61.6       64.7     11.95


                    SHEAR INDEX (N)    =   1.45

                    COHESION/ TENSILE
                            STRENGTH =   4.40
```

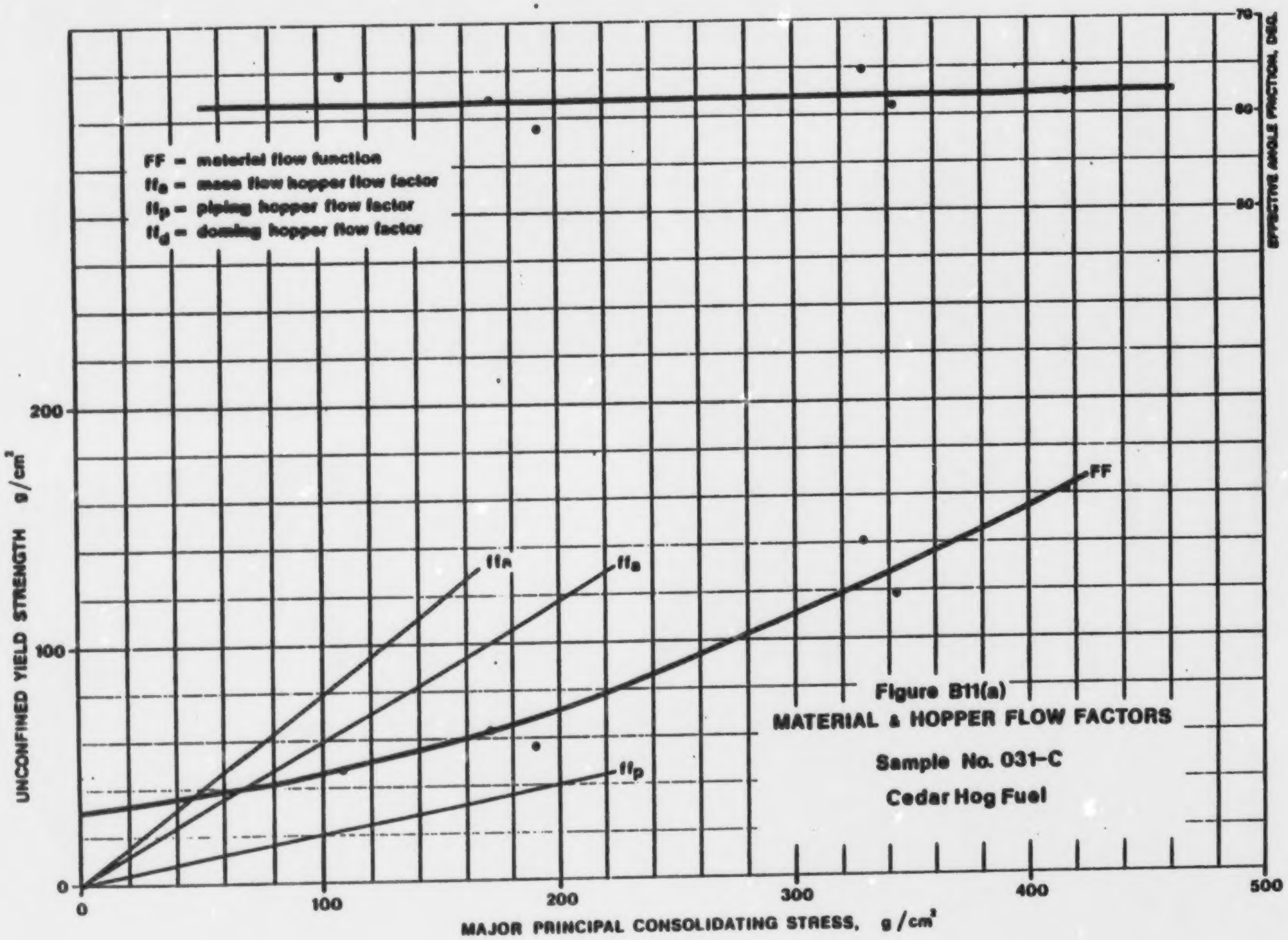

Figure B11(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 031-C
Cedar Hog Fuel

TABLE B12 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEM.- FIR HOG FUEL (FRASER MILLS) SAMPLE # 033

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	40.0		
		2.5	6.8
		4.2	11.1
		8.4	19.1
		12.6	23.1
		16.8	30.0
		24.4	34.4
		27.0	40.0
48.1	71.6		
		4.2	13.5
		8.4	27.1
		16.8	38.4
		27.0	39.3
		33.7	56.1
		39.6	65.5
		48.1	71.6
59.9	86.6		
		4.2	16.5
		8.4	32.9
		16.8	43.7
		27.0	45.2
		43.8	65.5
		56.5	76.8
		59.9	86.6
81.8	111.2		
		4.2	33.3
		12.6	38.9
		27.0	52.0
		56.5	86.4
		59.9	91.1
		73.4	99.2
		81.8	111.2
98.7	140.4		
		4.2	21.2
		12.6	30.4
		27.0	66.1
		56.5	99.1
		73.4	112.1
		90.3	125.1
		98.7	140.4
115.6	151.3		
		4.2	19.8
		12.6	48.7
		27.0	68.6
		56.5	109.6
		81.8	124.8
		107.1	136.7
		115.6	151.3

TABLE B12 (b)

HEM.- FIR HOG FUEL (FRASER MILLS) SAMPLE # 033 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRECS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	40.0	85.8	44.2	1.94	62.3	59.41	4.95	1.18
48.1	71.6	157.2	84.0	1.87	63.2	59.41	9.39	2.23
59.9	86.6	187.0	94.0	1.99	61.7	59.41	10.51	2.50
81.8	111.2	248.5	120.3	2.07	60.8	59.41	13.45	3.20
98.7	140.4	306.4	152.8	2.01	61.5	59.41	17.09	4.06
115.6	151.3	345.5	163.6	2.11	60.3	59.41	18.29	4.35

SHEAR INDEX (N) = 1.56

YIELD LOCUS	PERCENT FIT
1	99.3
2	98.8
3	99.2
4	99.5
5	99.5
6	99.5

TABLE B12 (c)

WALL FRICTION TEST RESULTS

HOG FUEL (B.H. LEVELTON & ASSOC.) SAMPLE 033

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	37.3
67.3	33.3
58.8	29.3
50.4	25.2
42.0	21.4
33.6	17.4
25.1	13.3
16.6	9.1
8.1	4.9
3.7	2.2

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	42.7
67.3	38.4
58.8	33.7
50.4	29.1
42.0	24.6
33.6	20.1
25.1	15.2
16.6	10.6
8.1	5.4
3.7	2.6

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	18.3
67.3	16.3
58.8	14.4
50.4	12.5
42.0	10.8
33.6	8.8
25.1	6.9
16.6	4.9
8.1	2.7
3.7	1.3

TABLE B12 (c) con't

WALL MATERIAL - PLASTIC COATING (DELTA PLASTICS)

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.8	35.5
67.3	32.6
58.8	29.2
50.4	25.6
42.0	21.9
33.6	18.5
25.1	14.2
16.6	10.0
8.1	5.3
3.7	2.3

TABLE B12 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

HEM-FIR HOG FUEL SAMPLE # 033

- TIME CONSOLIDATION RESULTS

CONSOLIDATION NORMAL STRESS	CONSOLIDATION SHEAR STRESS	YIELD POINT NORMAL STRESS	YIELD POINT SHEAR STRESS	FLOW PROPERTIES MAJ PRINC CONSOL'N STRESS INST	FLOW PROPERTIES MAJ PRINC CONSOL'N STRESS TIME	FLOW PROPERTIES UNCONFIN YIELD STRESS	FLOW PROPERTIES EFFECT FRIC ANGLE	FLOW PROPERTIES INTERNAL FRIC ANG AT FREE SURFACE	FLOW PROPERTIES COHESION
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20 HOURS									
48.1	58.0	48.1	64.5	157.2	146.6	70.6	60.8	59.5	7.89
59.9	72.3	59.9	81.1	187.0	184.4	90.1	61.2	59.5	10.07
81.8	121.9	81.8	122.9	248.5	283.4	160.8	64.8	59.5	17.97
98.7	137.0	98.7	143.5	306.4	329.2	178.3	63.6	59.5	19.93
CONSOLIDATION PERIOD 64 HOURS									
48.1	63.6	48.1	73.6	157.2	170.3	99.3	65.5	59.5	11.10

SHEAR INDEX (N) = 1.56

COHESION/ TENSILE STRENGTH = 4.19

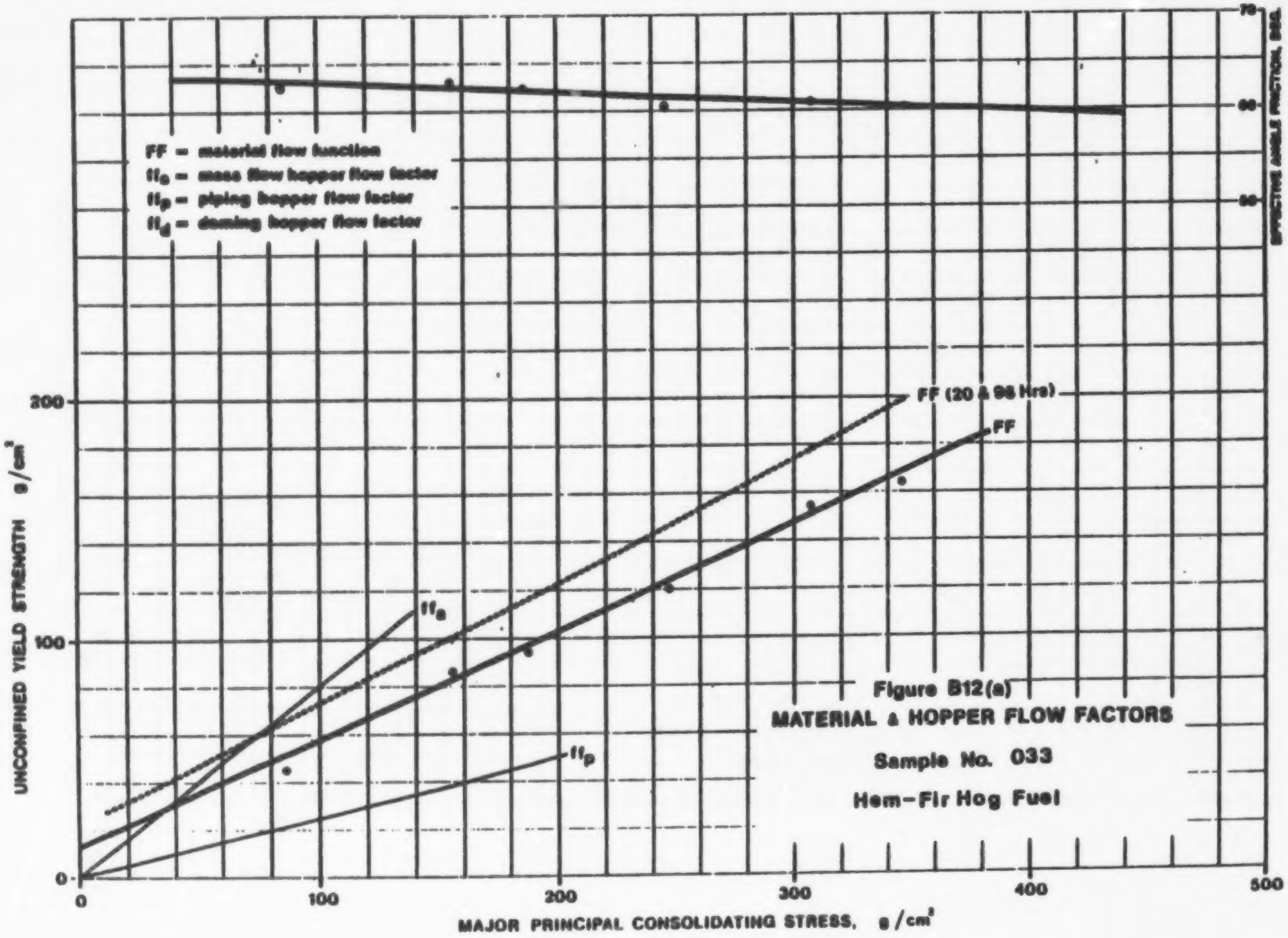

Figure B12(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 033
Hem-Fir Hog Fuel

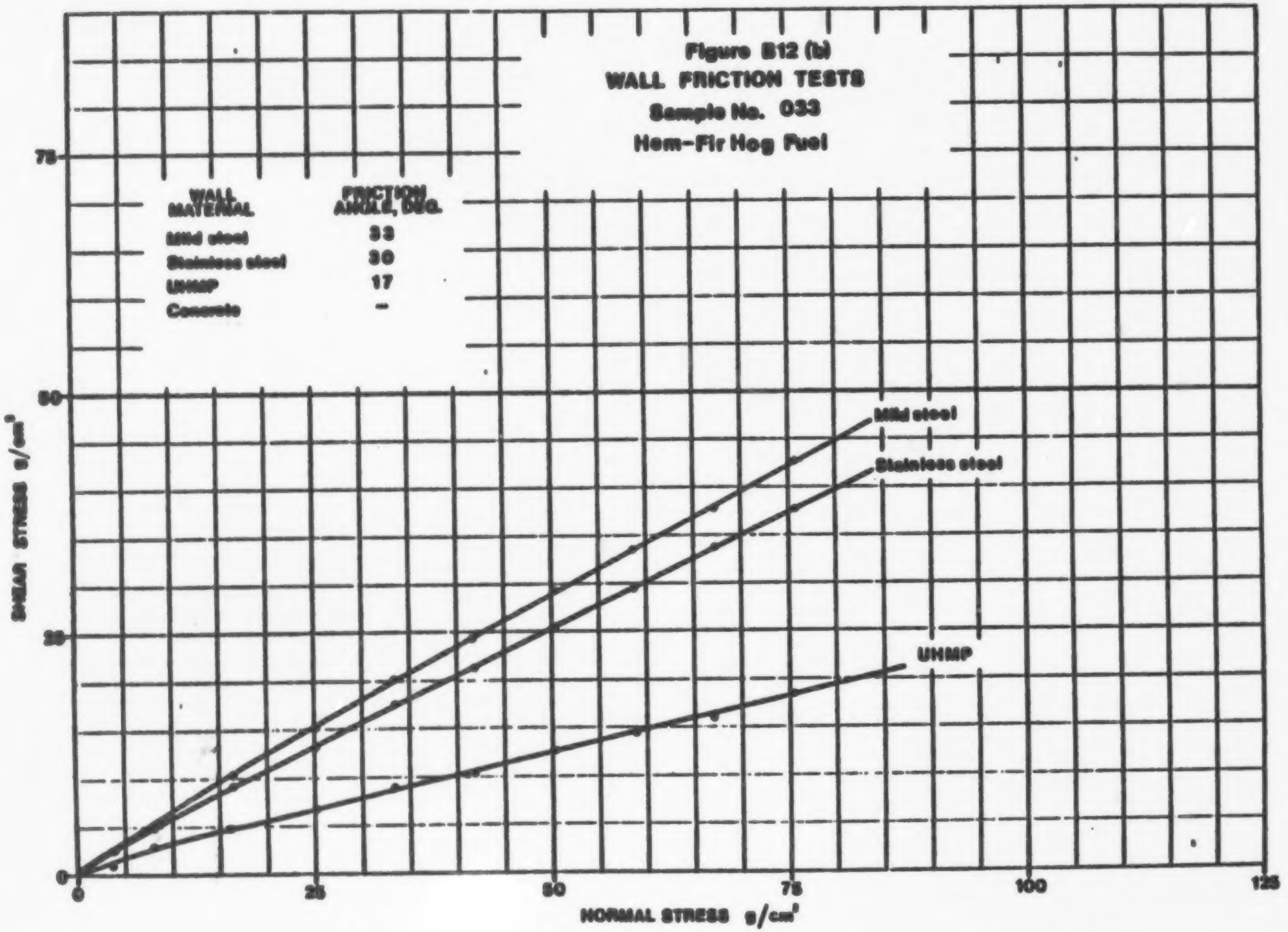

Figure B12 (b)
WALL FRICTION TESTS
Sample No. 033
Hem-Fir Hog Fuel

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	33
Stainless steel	30
UHMP	17
Concrete	–

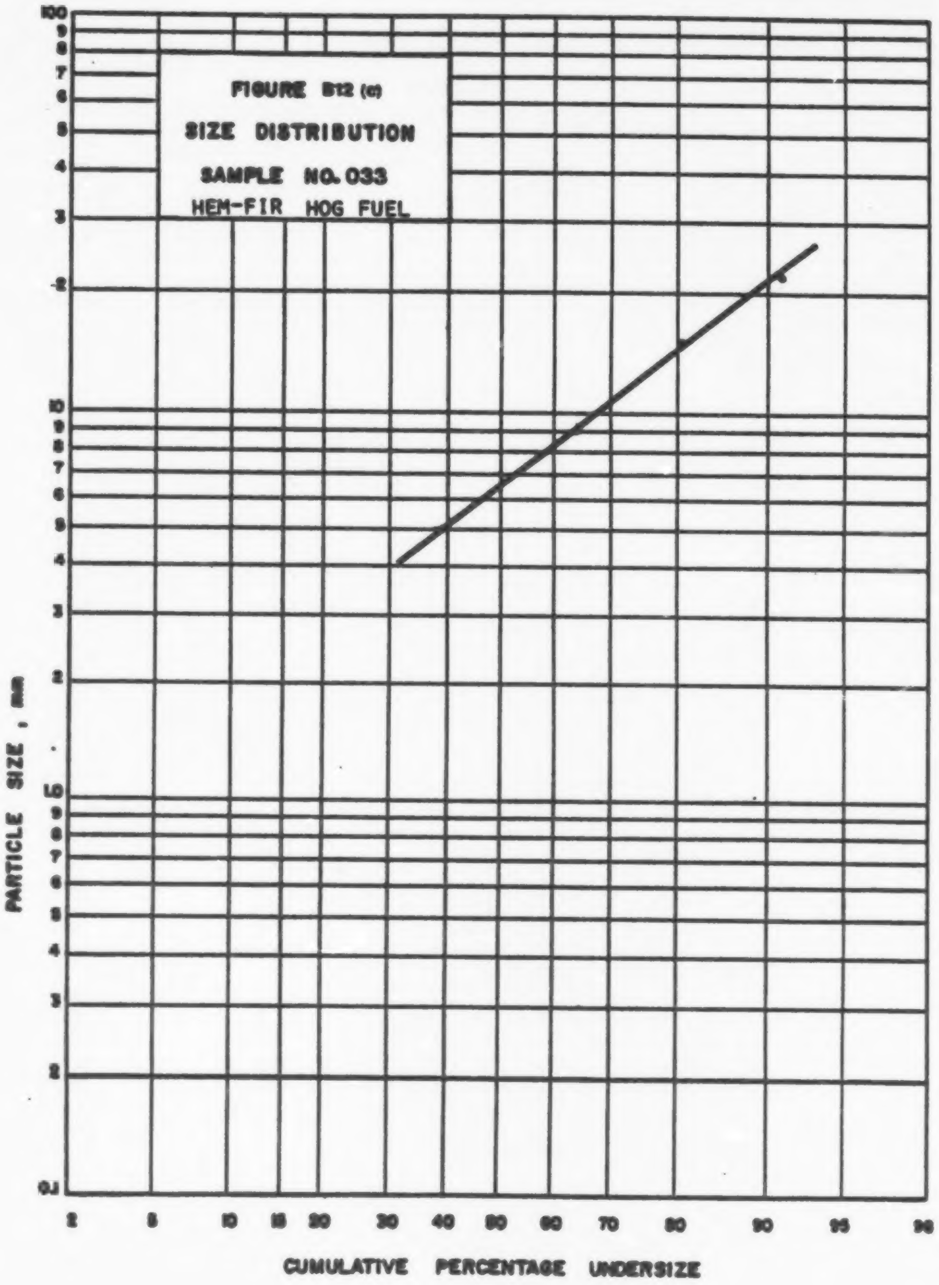

FIGURE B12 (c)

SIZE DISTRIBUTION

SAMPLE NO. 033

HEM-FIR HOG FUEL

TABLE B13 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEM.-FIR HOG FUEL (FRASER MILLS) SAMPLE #034

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	38.3		
		2.5	9.7
		4.2	11.1
		8.4	21.6
		12.6	23.7
		16.8	23.9
		24.4	32.6
		27.0	38.3
48.1	58.7		
		4.2	11.2
		8.4	20.3
		16.8	33.1
		27.0	45.1
		33.7	46.7
		39.6	51.5
		48.1	58.7
59.9	78.6		
		4.2	19.4
		8.4	21.2
		16.8	34.8
		27.0	44.2
		43.8	64.9
		56.5	77.4
		59.9	78.6
81.8	99.3		
		4.2	15.3
		12.6	35.4
		27.0	56.2
		56.5	84.9
		59.9	81.7
		73.4	98.6
		81.8	99.3
98.7	126.7		
		4.2	30.6
		12.6	35.3
		27.0	51.8
		56.5	87.6
		73.4	97.2
		90.3	116.1
		98.7	126.7
115.6	139.2		
		4.2	18.7
		12.6	66.0
		27.0	66.1
		56.5	86.2
		81.8	124.5
		107.1	124.8
		115.6	139.2

TABLE B13 (b)

HEM.-FIR HOG FUEL (FRASER MILLS) SAMPLE #034 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	38.3	79.4	45.0	1.77	61.7	55.85	5.60	1.43
48.1	58.7	129.5	64.8	2.00	58.4	55.85	8.06	2.05
59.9	78.6	169.9	91.4	1.86	60.3	55.85	11.37	2.90
81.8	99.3	225.2	116.1	1.94	59.1	55.85	14.45	3.68
98.7	126.7	268.8	136.5	1.97	58.7	55.85	16.99	4.33
115.6	139.2	313.3	158.0	1.98	58.6	55.85	19.66	5.01

SHEAR INDEX (N) = 1.61

YIELD LOCUS	PERCENT FIT
1	99.0
2	99.5
3	99.6
4	99.6
5	99.7
6	98.2

TABLE B13 (c)

WALL FRICTION TEST RESULTS

HOG FUEL (B.H. LEVELTON & ASSOC.) SAMPLE 034

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.2	38.0
67.7	34.2
59.2	30.1
50.8	26.0
42.3	22.0
33.9	17.8
25.4	13.8
16.9	9.6
8.4	5.2
4.1	2.6

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.2	42.5
67.7	38.2
59.2	33.9
50.8	30.4
42.3	24.6
33.9	20.1
25.4	15.4
16.9	10.7
8.4	5.6
4.1	2.7

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.2	16.3
67.7	14.9
59.2	13.1
50.8	11.5
42.3	9.8
33.9	8.1
25.4	6.3
16.9	4.5
8.4	2.6
4.1	1.4

TABLE B13 (c) con't

WALL MATERIAL - DELTA PLASTICS COATING

NORMAL STRESS G/SQ CM.	SHEAR STRESS G/SQ CM
76.2	34.8
67.7	32.4
59.2	29.2
50.8	25.6
42.3	22.2
33.9	19.0
25.4	15.1
16.9	10.7
8.4	5.7
4.1	2.6

TABLE B13 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

HEM-FIR HOG FUEL SAMPLE # 034

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<----FLOW PROPERTIES----					---->
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS INST	TIME	UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20 HOURS									
27.0	33.5	27.0	36.5	79.4	81.4	47.3	62.5	55.9	5.89
48.1	59.3	48.1	62.4	129.5	138.9	76.1	60.9	55.9	9.48
59.9	78.0	59.9	88.6	169.9	199.4	130.1	65.9	55.9	16.21
81.8	106.1	81.8	104.2	225.2	231.8	123.7	60.1	55.9	15.40
115.6	126.4	115.6	143.5	313.3	319.1	164.1	59.2	55.9	20.44
CONSOLIDATION PERIOD 88 HOURS									
98.7	109.8	98.7	127.9	268.8	284.7	155.7	60.8	55.9	19.39

SHEAR INDEX (N) = 1.61

COHESION/ TENSILE
STRENGTH = 3.90

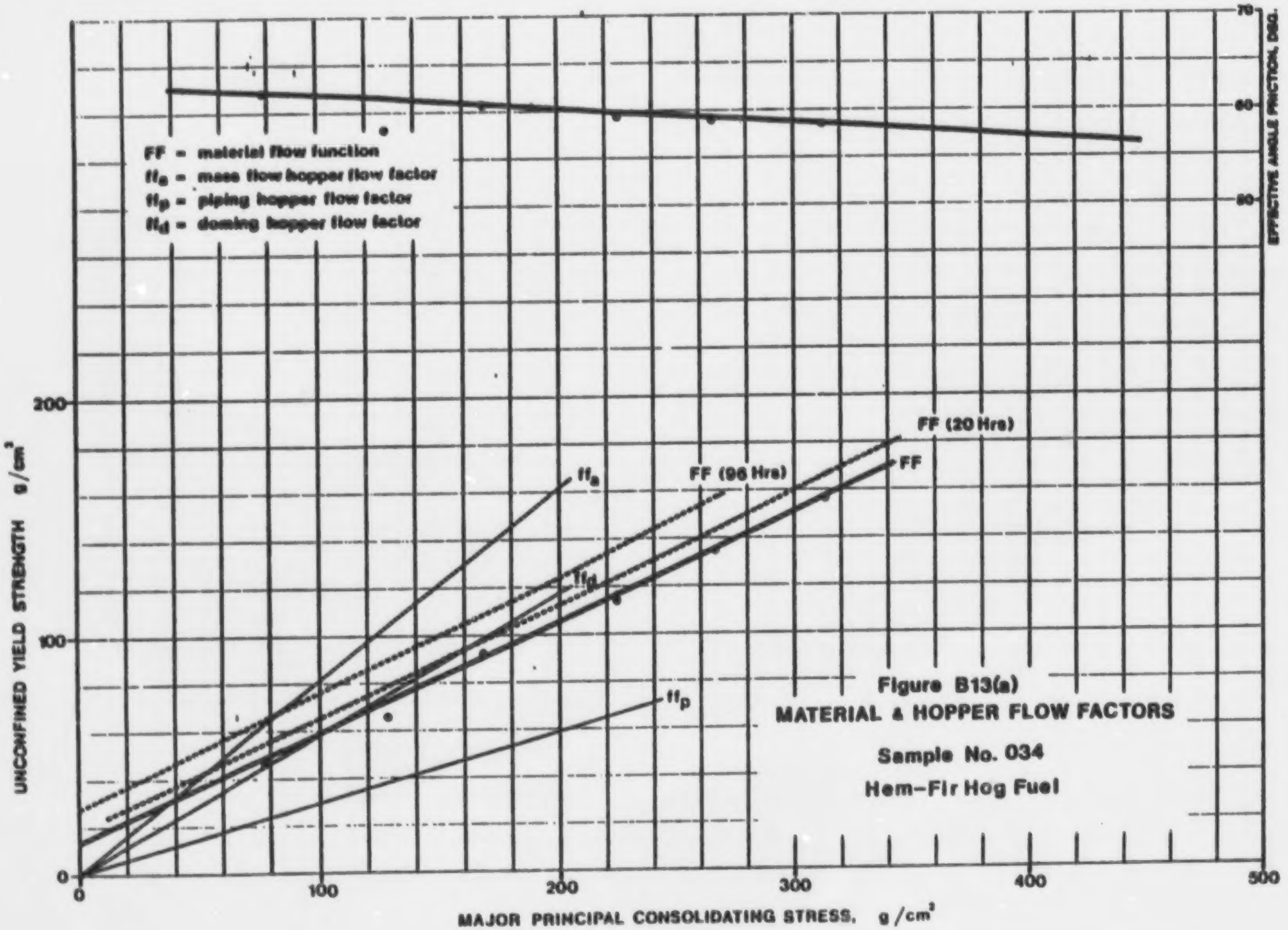

Figure B13(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 034
Hem-Fir Hog Fuel

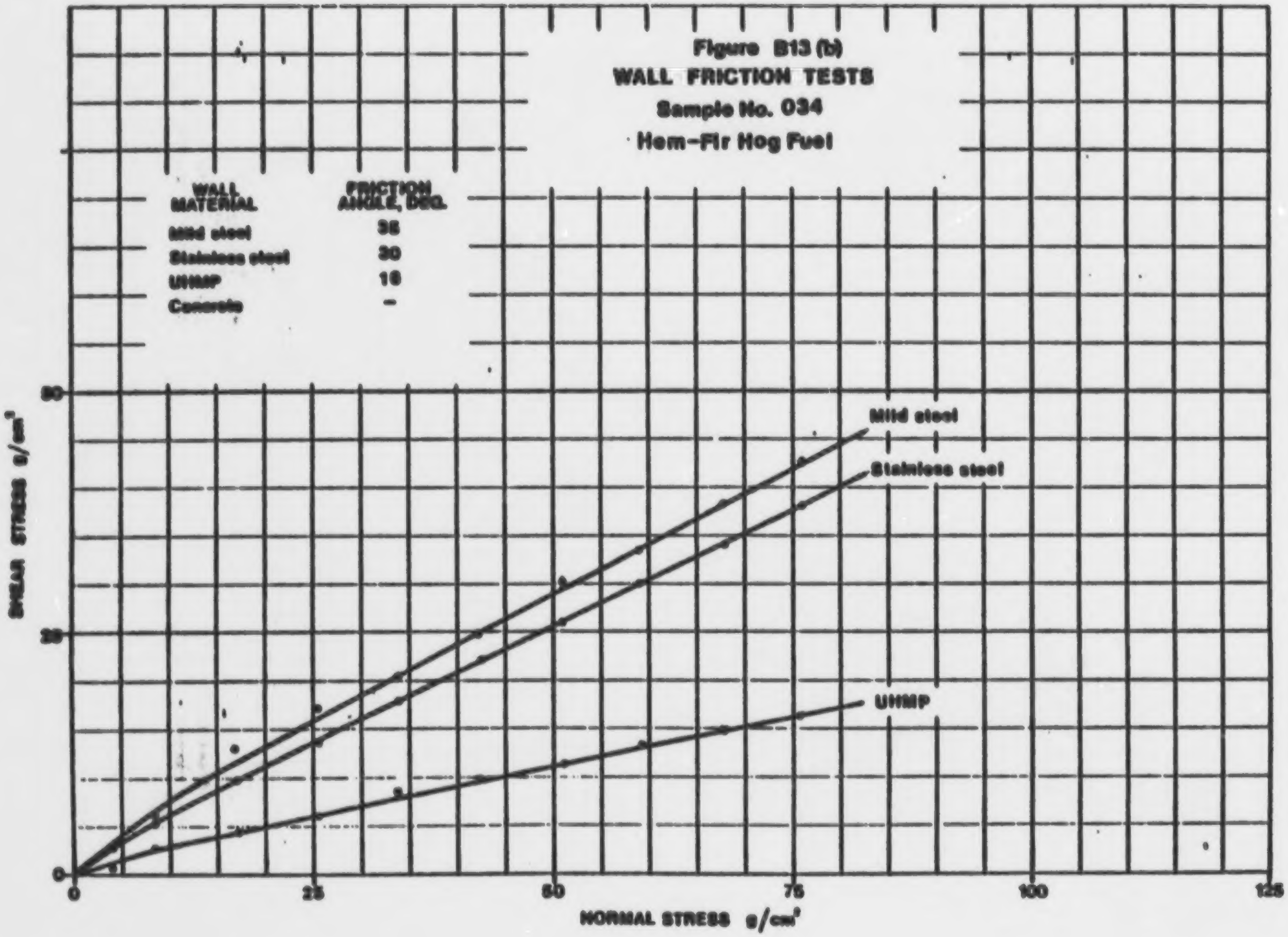

Figure B13 (b)
WALL FRICTION TESTS
Sample No. 034
Hem-Fir Hog Fuel

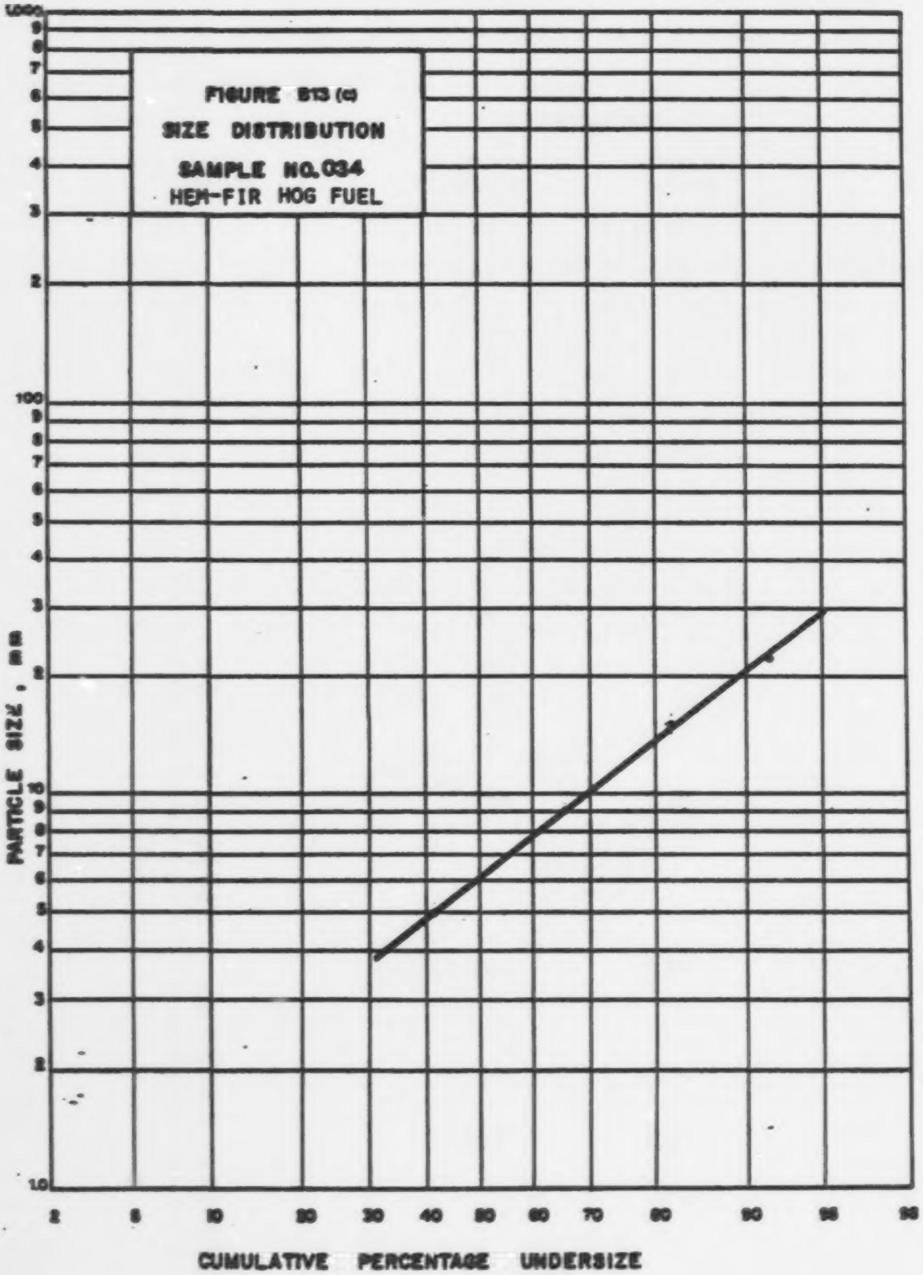

FIGURE B13 (c)
SIZE DISTRIBUTION
SAMPLE NO. 034
HEM-FIR HOG FUEL

TABLE B14 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK HOG FUEL (MB-C. WHITE PINE DIV.) SAMPLE # 035

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	34.3		
		2.5	8.0
		4.2	11.9
		8.4	17.3
		12.6	27.7
		16.8	32.1
		24.4	34.1
		27.0	34.3
48.1	57.9		
		4.2	17.3
		8.4	27.5
		16.8	31.0
		27.0	42.7
		33.7	48.3
		39.6	49.2
		48.1	57.9
59.9	73.4		
		4.2	15.9
		8.4	24.8
		16.8	35.8
		27.0	52.7
		43.8	58.7
		56.5	70.0
		59.9	73.4
81.8	120.4		
		4.2	18.5
		12.6	34.4
		27.0	44.3
		56.5	84.2
		59.9	90.0
		73.4	100.1
		81.8	120.4
98.7	133.2		
		4.2	18.7
		12.6	45.1
		27.0	74.9
		56.5	109.1
		73.4	110.4
		90.3	127.9
		98.7	133.2
115.6	151.0		
		4.2	13.7
		12.6	44.7
		27.0	64.9
		56.5	121.1
		81.8	134.2
		107.1	142.6
		115.6	151.0

TABLE B14 (b)

HEMLOCK HOG FUEL (MB-C. WHITE PINE DIV.) SAMPLE # 035 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	34.3	81.8	47.8	1.71	62.8	56.54	5.76	1.39
48.1	57.9	130.0	65.2	1.99	58.6	56.54	7.85	1.89
59.9	73.4	163.1	82.6	1.98	58.9	56.54	9.94	2.40
81.8	120.4	237.8	131.6	1.81	61.3	56.54	15.85	3.83
98.7	133.2	303.3	180.1	1.68	63.3	56.54	21.68	5.23
115.6	151.0	343.8	196.0	1.75	62.1	56.54	23.59	5.69

SHEAR INDEX (N) = 1.63

YIELD LOCUS	PERCENT FIT
1	98.5
2	99.5
3	99.6
4	98.7
5	99.3
6	98.6

TABLE B14 (c)

WALL FRICTION TEST RESULTS

HEMLOCK HOG FUEL (MB - CAN. WHITE PINE DIV.) SAMPLE 035

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.5	36.6
68.0	32.8
59.5	28.9
51.1	24.9
42.7	21.0
34.3	17.2
25.8	13.2
17.3	9.2
8.8	5.3
4.4	2.9

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.5	40.6
68.0	36.6
59.5	32.3
51.1	27.9
42.7	23.5
34.3	19.1
25.8	14.7
17.3	10.3
8.8	5.6
4.4	2.8

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.5	16.7
68.0	13.4
59.5	11.6
51.1	10.1
42.7	8.5
34.3	6.9
25.8	5.4
17.3	3.9
8.8	2.5
4.4	1.4

TABLE B14 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

HEMLOCK HOG FUEL SAMPLE # 035

                        .- TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT     <---------------FLOW PROPERTIES---------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC     UNCONFIN  EFFECT   INTERNAL  COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N      YIELD     FRIC     FRIC ANG
                                  STRESS      STRESS    ANGLE    AT FREE
                                INST    TIME                       SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM      G/SQ CM    DEG       DEG     G/SQ CM

CONSOLIDATION PERIOD  20 HOURS

  48.1    56.8    48.1    66.3  130.0  147.7   88.2     63.3      56.4     10.65
  59.9    70.5    59.9    74.9  163.1  166.1   86.8     59.6      56.4     10.48
  98.7   127.9    98.7   142.3  303.3  318.5  201.4     65.1      56.4     24.32
 115.6   151.9   115.6   160.7  343.8  358.4  216.4     63.7      56.4     26.12
CONSOLIDATION PERIOD  89 HOURS

  81.8    95.5    81.8   107.1  237.8  237.8  132.5     61.4      56.4     15.99


                        SHEAR INDEX (N)    =   1.63

                        COHESION/ TENSILE
                              STRENGTH =   4.14
```

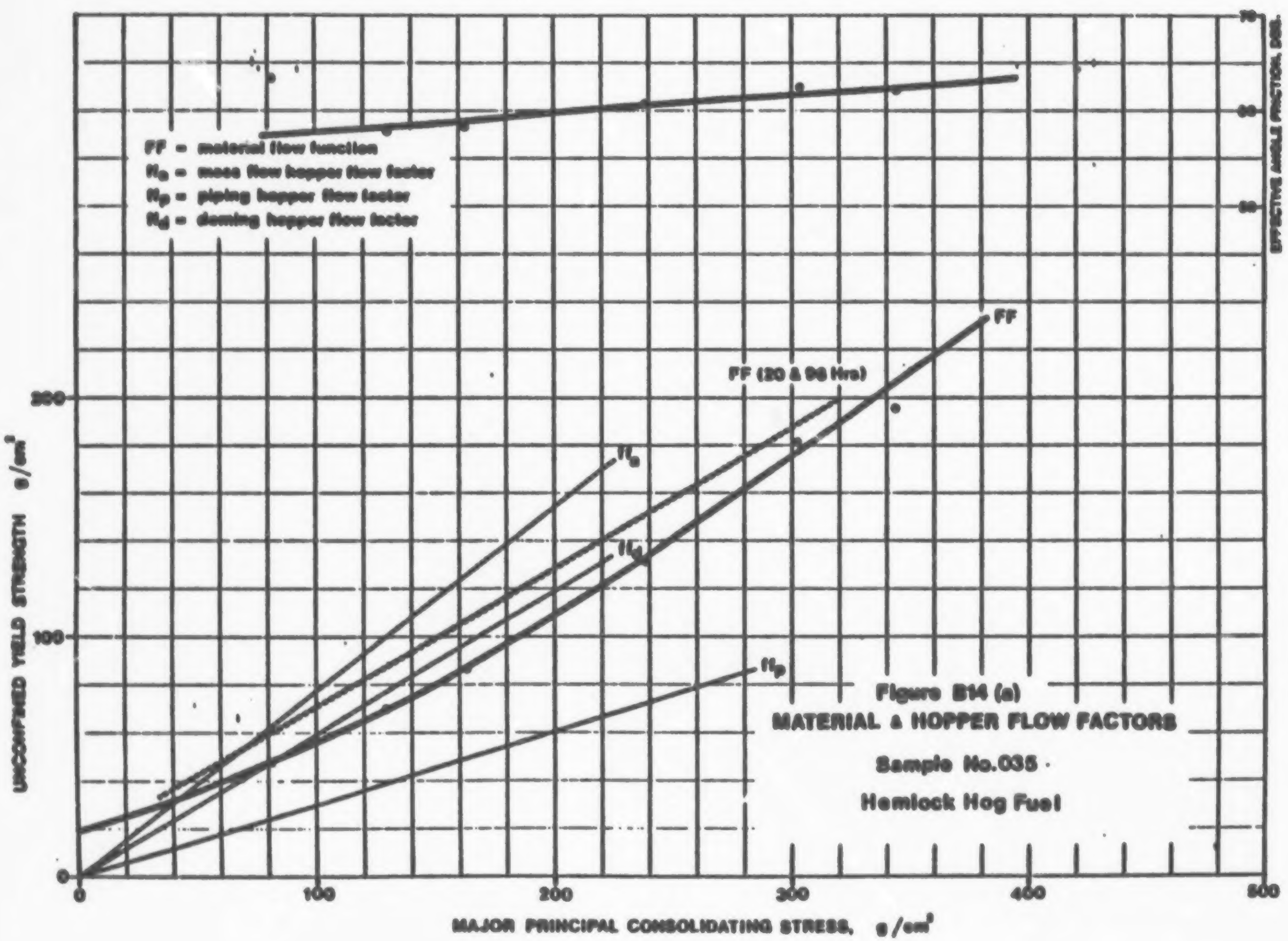

Figure B14 (a)
MATERIAL & HOPPER FLOW FACTORS
Sample No.035
Hemlock Hog Fuel

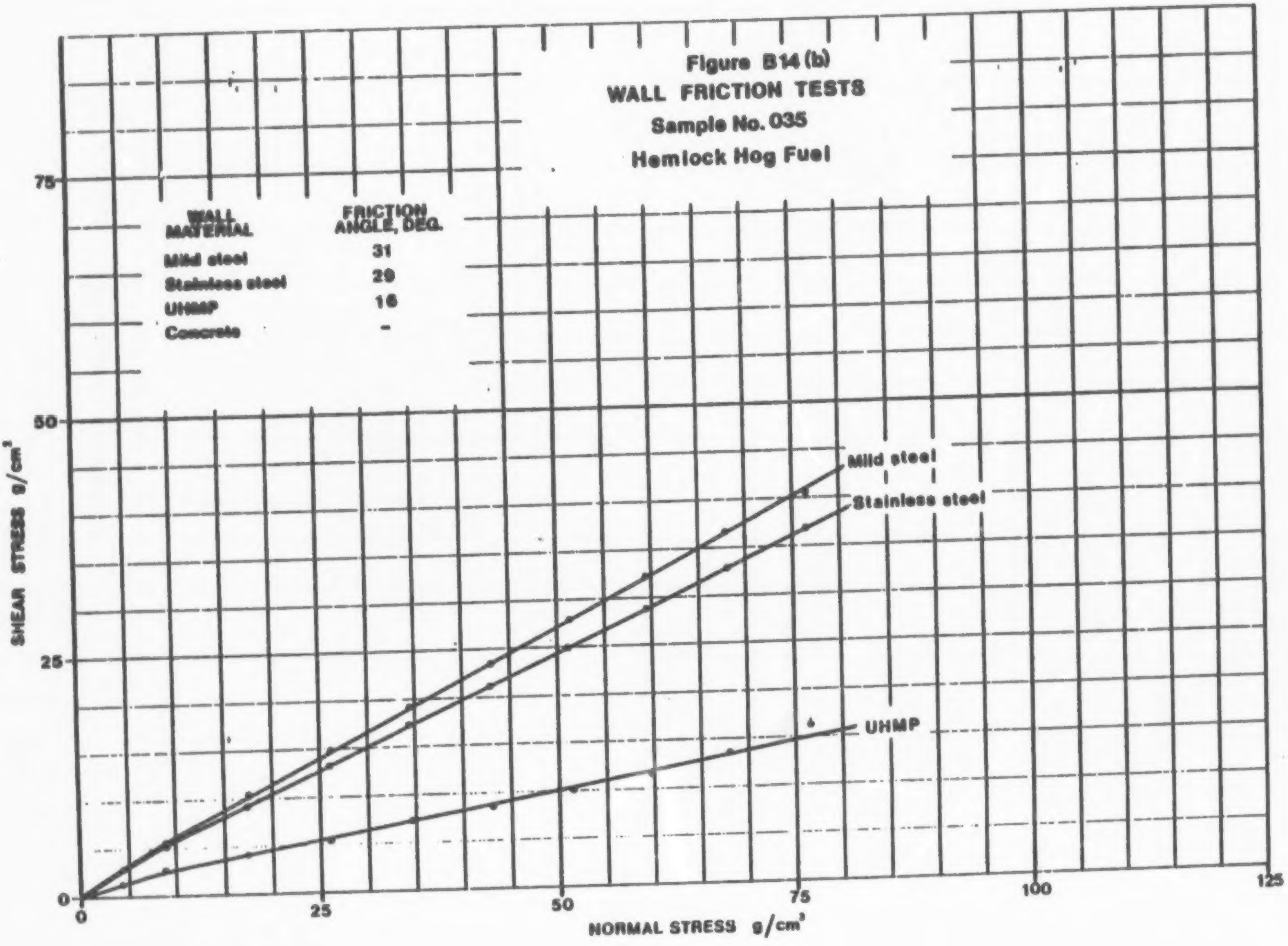

Figure B14 (b)
WALL FRICTION TESTS
Sample No. 035
Hemlock Hog Fuel

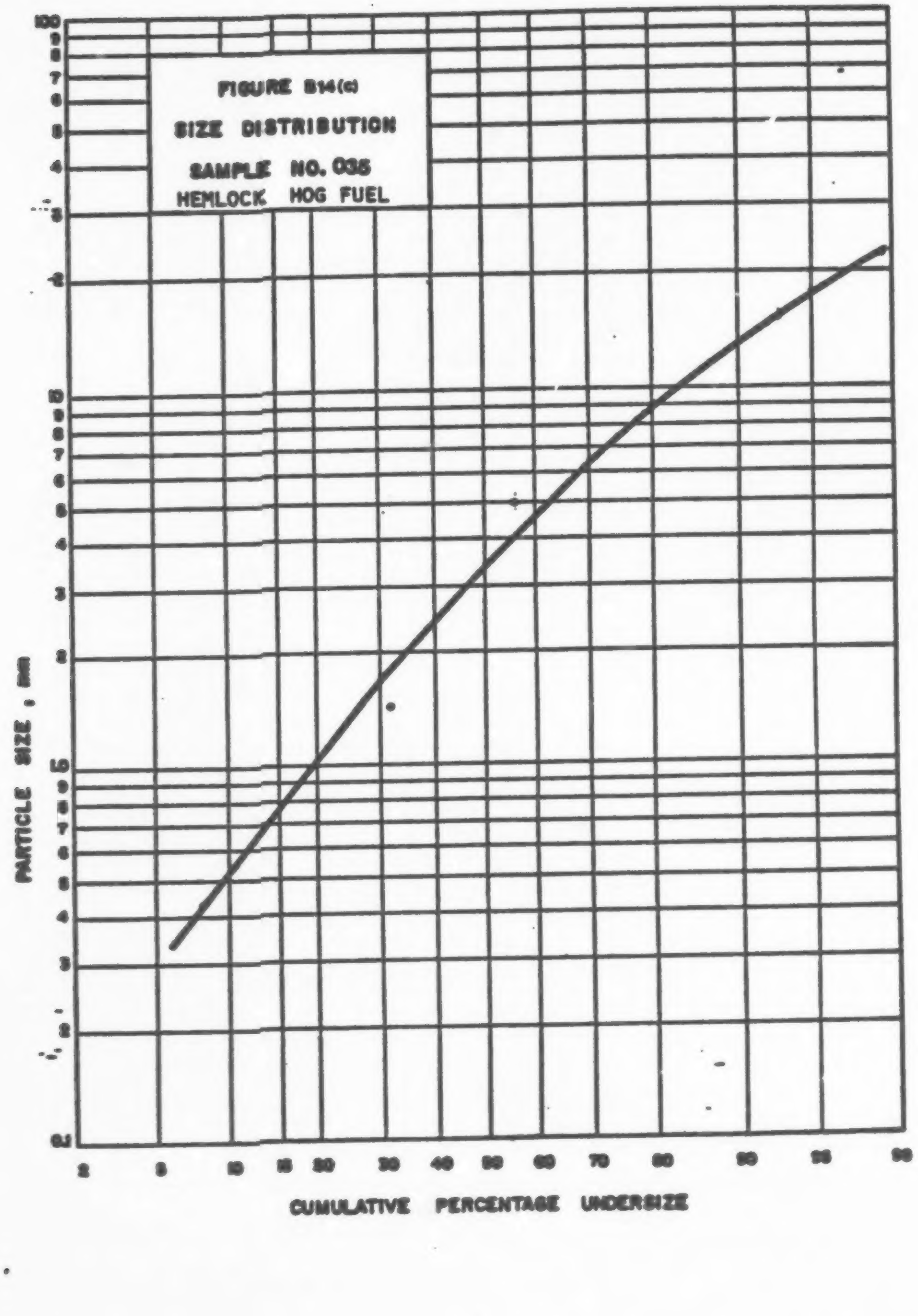

FIGURE B14(c)

SIZE DISTRIBUTION

SAMPLE NO. 035
HEMLOCK HOG FUEL

TABLE B15 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK HOG FUEL (C. WHITE PINE) SAMPLE # 035-C

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	37.7		
		2.5	8.3
		4.2	20.3
		8.4	35.6
		12.6	23.9
		16.8	26.2
		24.4	33.9
		27.0	37.7
48.1	67.0		
		4.2	12.7
		8.4	23.0
		16.8	36.8
		27.0	49.9
		33.7	54.2
		39.6	64.3
		48.1	67.0
59.9	83.1		
		4.2	23.2
		8.4	30.2
		16.8	37.4
		27.0	49.6
		43.8	76.8
		56.5	81.7
		59.9	83.1
81.8	114.4		
		4.2	24.4
		12.6	44.1
		27.0	75.4
		56.5	83.6
		59.9	92.5
		73.4	98.1
		81.8	114.4
98.7	129.8		
		4.2	13.3
		12.6	35.8
		27.0	62.9
		56.5	98.7
		73.4	109.8
		90.3	116.1
		98.7	129.8
115.6	142.6		
		4.2	31.2
		12.6	54.3
		27.0	79.6
		56.5	117.0
		81.8	112.9
		107.1	118.6
		115.6	142.6

TABLE B15 (b)

HEMLOCK HOG FUEL (C. WHITE PINE) SAMPLE # 033-C (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	37.7	78.1	67.8	1.15	72.0	45.84	10.02	2.24
48.1	67.0	131.5	108.3	1.21	68.7	45.84	15.99	3.57
59.9	83.1	165.5	137.6	1.20	69.3	45.84	20.33	4,54
81.8	114.4	221.5	180.5	1.23	68.1	45.84	26.67	5.96
98.7	129.8	230.5	190.9	1.31	64.5	45.84	28.20	6.30
115.6	142.6	289.1	216.6	1.33	63.7	45.84	32.01	7.15

SHEAR INDEX (N) =- 1.94

YIELD LOCUS	PERCENT FIT
1	93.9
2	98.0
3	98.7
4	99.0
5	97.9
6	98.6

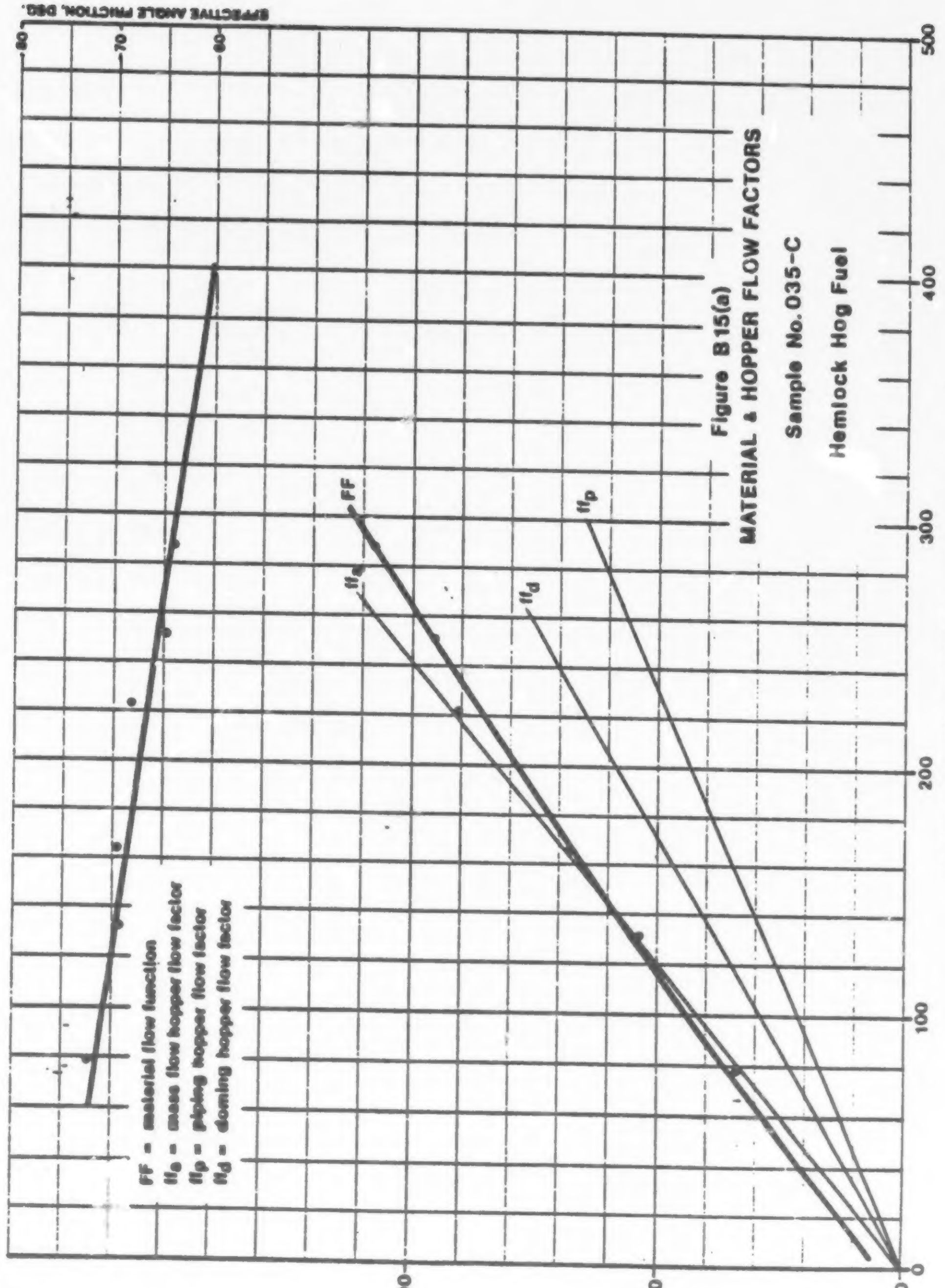

Figure B15(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 035-C
Hemlock Hog Fuel

TABLE B16 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR HOG FUEL SAMPLE # 036 (C. WHITE PINE)

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	37.4	2.5	6.6
		4.2	10.5
		8.4	15.6
		12.6	20.2
		16.8	23.6
		24.4	32.4
		27.0	37.4
48.1	61.4	4.2	11.1
		8.4	25.8
		16.8	33.7
		27.0	52.4
		33.7	54.1
		39.6	54.8
		48.1	61.4
59.9	108.3	4.2	14.5
		8.4	25.0
		16.8	42.7
		27.0	54.5
		43.8	76.6
		56.5	84.9
		59.9	108.3
81.8	106.1	4.2	19.7
		12.6	30.8
		27.0	50.8
		56.5	84.0
		59.9	87.7
		73.4	98.0
		81.8	106.1
98.7	129.2	4.2	17.2
		12.6	35.4
		27.0	64.4
		56.5	100.2
		73.4	105.1
		90.3	112.3
		98.7	129.2
115.6	173.2	4.2	17.7
		12.6	41.0
		27.0	63.4
		56.5	116.2
		81.8	141.0
		107.1	143.5
		115.6	173.2

TABLE B16 (b)

CEDAR HOG FUEL SAMPLE # 036 (C. WHITE PINE) (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	37.4	82.1	24.3	3.38	57.5	63.10	2.51	.63
48.1	61.4	157.1	52.7	2.98	59.5	63.10	5.43	1.36
59.9	108.3	233.3	102.6	2.27	64.1	63.10	10.58	2.66
81.8	106.1	251.4	75.7	3.32	57.7	63.10	7.80	1.96
98.7	129.2	306.7	94.2	3.26	58.1	63.10	9.71	2.44
115.6	173.2	401.9	149.1	2.69	61.2	63.10	15.37	3.86

SHEAR INDEX (N) = 1.43

YIELD LOCUS	PERCENT FIT
1	99.6
2	98.8
3	98.9
4	100.0
5	99.2
6	99.2

TABLE B16 (c)

WALL FRICTION TEST RESULTS

CEDAR HOG FUEL (MB - CAN. WHITE PINE DIV.) SAMPLE 036

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	37.1
66.7	33.4
58.2	29.4
49.8	25.3
41.3	21.5
32.9	17.5
24.4	13.6
15.9	9.5
7.4	5.2
3.1	2.4

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	42.3
66.7	38.0
58.2	33.7
49.8	29.2
41.3	24.6
32.9	20.0
24.4	15.4
15.9	10.4
7.4	5.2
3.1	2.2

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	19.9
66.7	17.7
58.2	15.7
49.8	13.6
41.3	11.6
32.9	9.6
24.4	7.5
15.9	5.4
7.4	3.0
3.1	1.6

TABLE B16 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

CEDAR HOGFUEL (SAMPLE # 036)

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<--FLOW PROPERTIES-->					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS INST	MAJ PRINC CONSOL'N STRESS TIME	UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20 HOURS									
48.1	68.0	48.1	68.0	157.1	159.9	55.9	61.0	63.3	5.73
81.8	116.3	81.8	116.3	251.4	273.6	96.5	61.1	63.3	9.90
98.7	147.3	98.7	147.3	306.7	348.5	135.2	62.8	63.3	13.87
115.6	170.0	115.6	170.0	401.9	401.6	151.6	62.3	63.3	15.55
CONSOLIDATION PERIOD 68 HOURS									
59.9	93.2	59.9	93.2	233.3	222.0	93.5	64.4	63.3	9.59

SHEAR INDEX (N) = 1.43

COHESION/ TENSILE
STRENGTH = 3.98

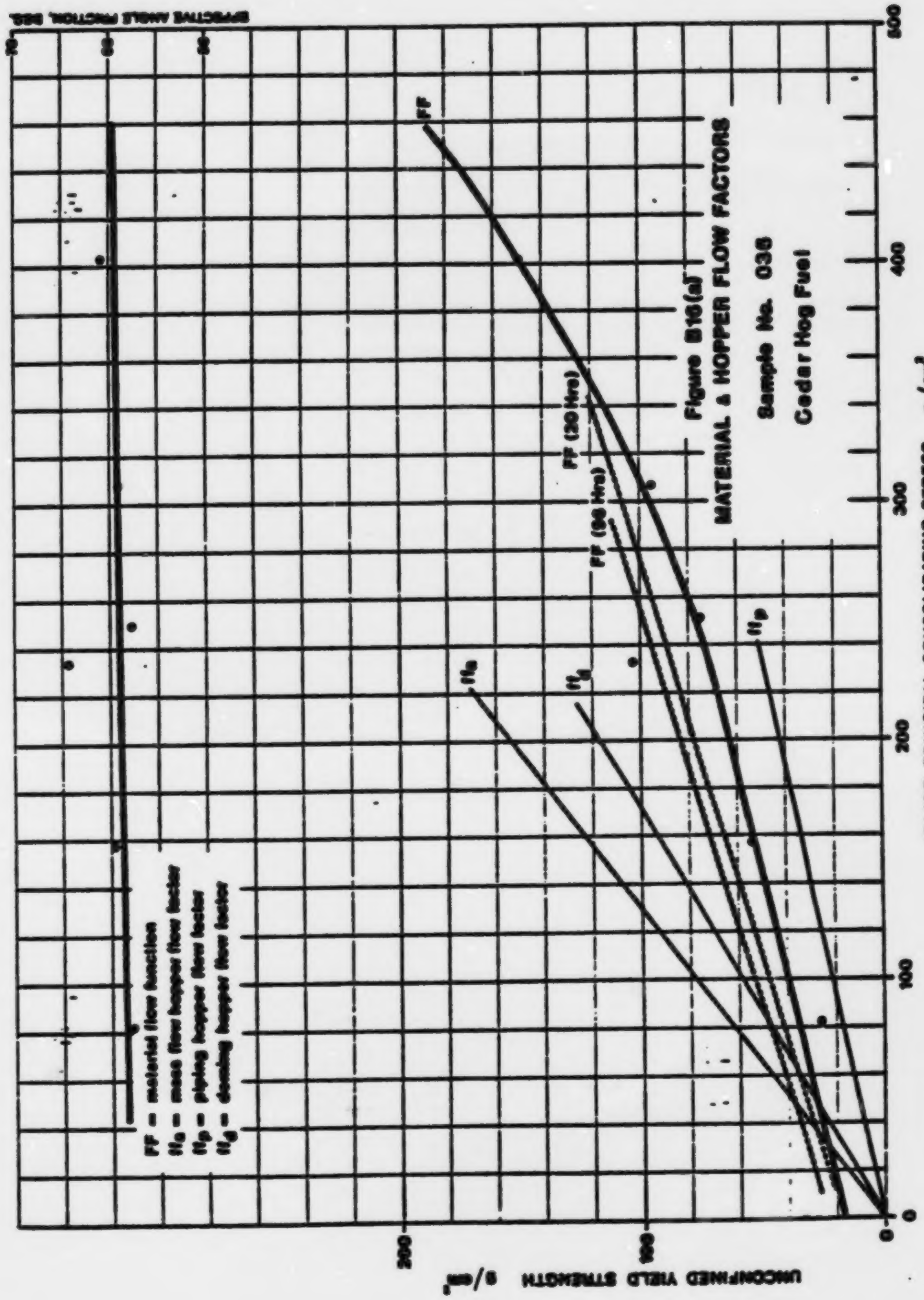

Figure B16(a)

MATERIAL & HOPPER FLOW FACTORS

Sample No. 036

Cedar Hog Fuel

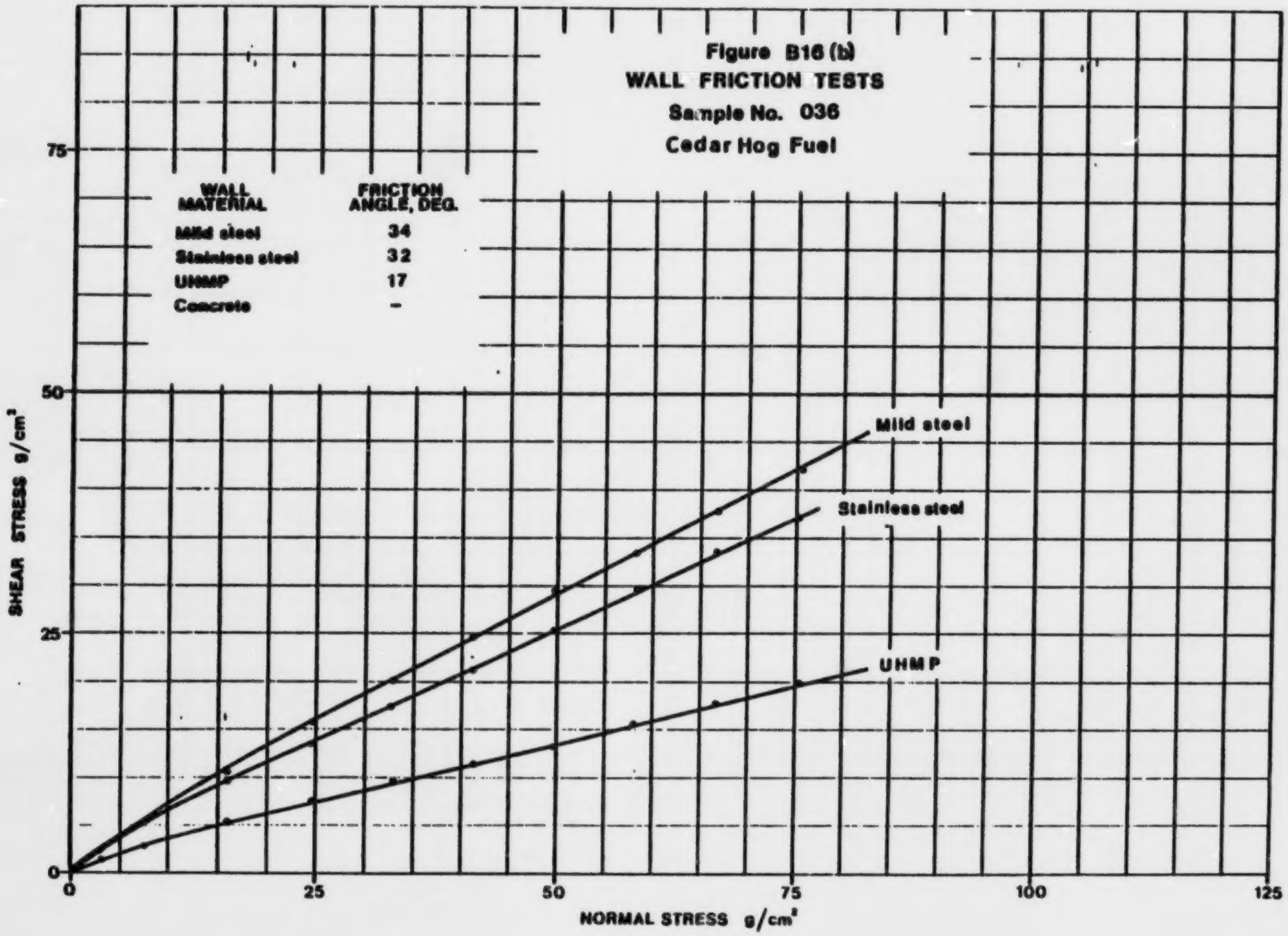

Figure B16 (b)
WALL FRICTION TESTS
Sample No. 036
Cedar Hog Fuel

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	34
Stainless steel	32
UHMP	17
Concrete	-

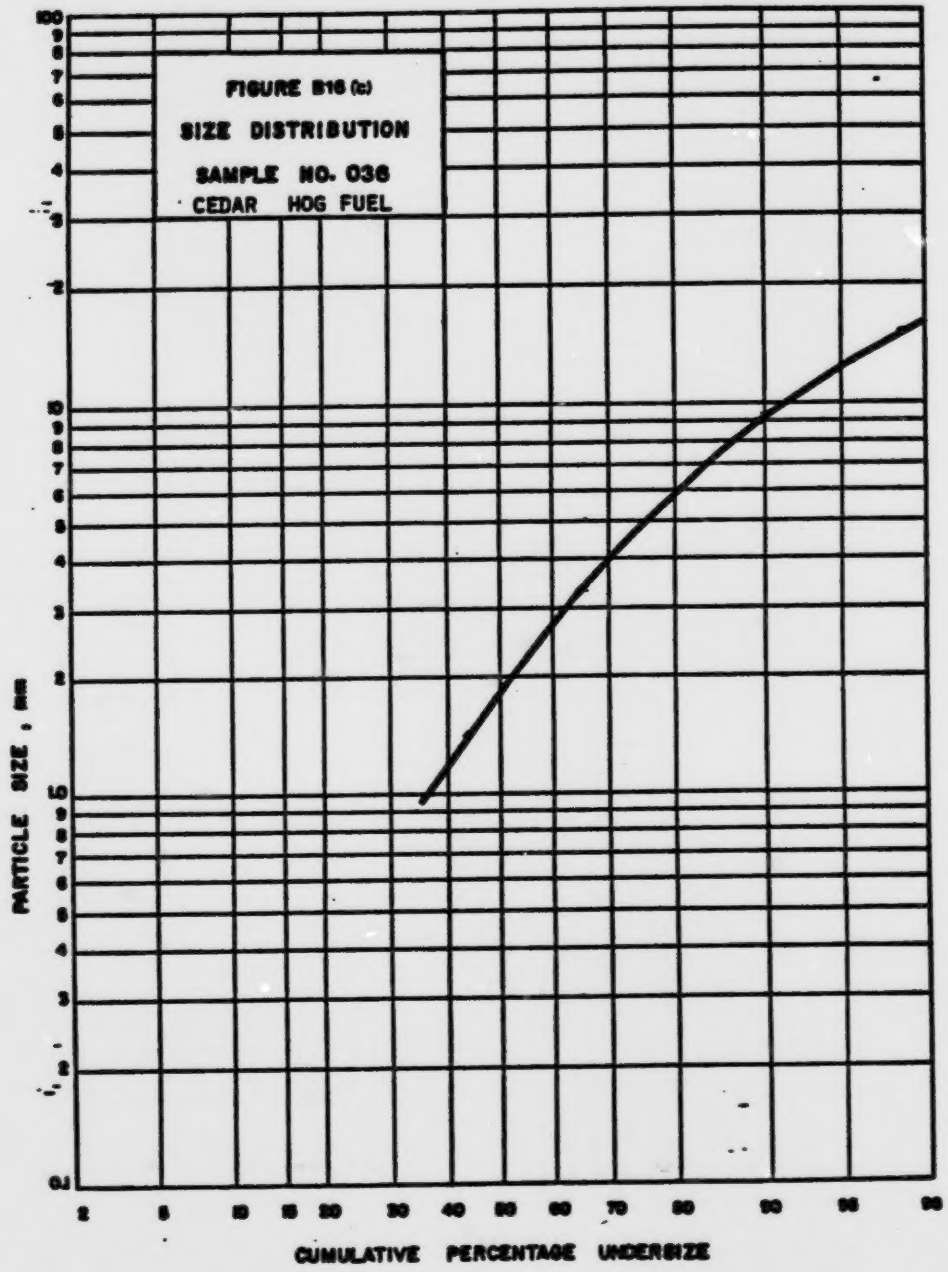

FIGURE B16 (c)

SIZE DISTRIBUTION

SAMPLE NO. 036

CEDAR HOG FUEL

TABLE B17 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR HOG FUEL SAMPLE # 036-C (C.WHITE PINE)

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM
27.0	47.8		
		2.5	10.5
		4.2	19.0
		8.4	22.8
		12.6	28.3
		16.8	34.9
		24.4	35.6
		27.0	47.8
48.1	77.9		
		4.2	9.5
		8.4	21.1
		16.8	41.4
		27.0	56.9
		33.7	59.3
		39.6	68.0
		48.1	77.9
59.9	75.5		
		4.2	17.2
		8.4	23.2
		16.8	38.4
		27.0	48.0
		43.8	60.8
		56.5	71.8
		59.9	75.5
81.8	107.1		
		4.2	15.5
		12.6	34.3
		27.0	58.8
		56.5	81.7
		59.9	99.2
		73.4	104.8
		81.8	107.1
98.7	139.2		
		4.2	11.7
		12.6	36.5
		27.0	67.0
		56.5	109.6
		73.4	107.6
		90.3	131.4
		98.7	139.2
115.6	167.5		
		4.2	17.8
		12.6	46.9
		27.0	87.7
		56.5	129.5
		81.8	131.4
		107.1	132.6
		115.6	167.5

TABLE B17 (b)

CEDAR HOG FUEL SAMPLE # 036-C (C.WHITE PINE) (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	47.8	100.2	68.5	1.46	68.8	58.62	7.62	1.68
48.1	77.9	167.4	107.2	1.56	66.8	58.62	11.93	2.62
59.9	75.5	166.6	81.4	2.05	59.3	58.62	9.05	1.99
81.8	107.1	242.6	129.0	1.88	61.5	58.62	14.35	3.15
98.7	139.2	304.4	170.0	1.79	62.8	58.62	18.91	4.16
115.6	167.5	363.9	208.4	1.75	63.5	58.62	23.17	5.09

SHEAR INDEX (N) = 1.63

YIELD LOCUS	PERCENT FIT
1	98.6
2	98.4
3	99.9
4	99.3
5	98.9
6	97.7

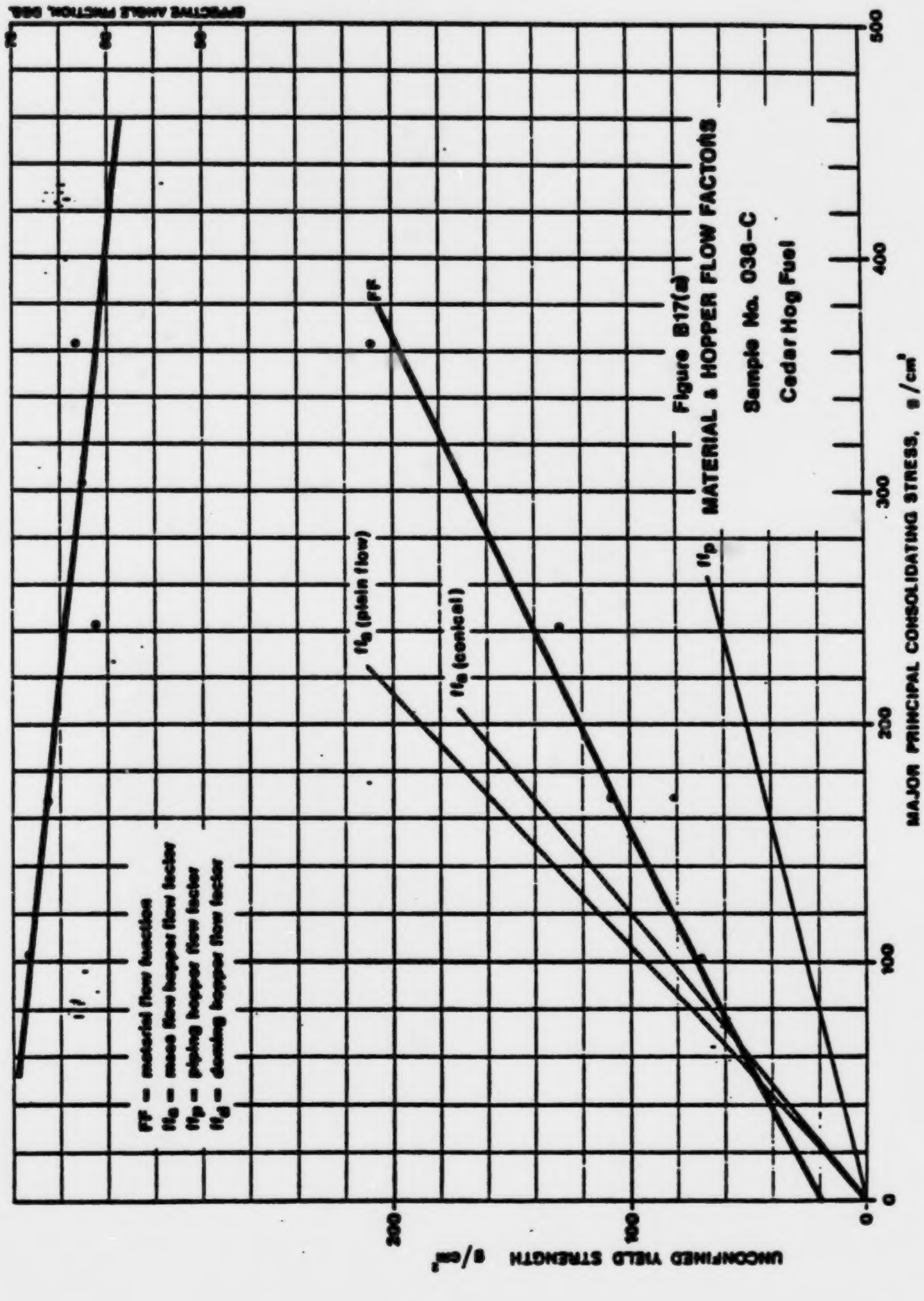

Figure B17(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 036-C
Cedar Hog Fuel

TABLE B18 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK-FIR HOG FUEL (FRASER MILLS) SAMPLE # 040

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	38.6		
		2.5	15.2
		4.2	16.7
		8.4	17.5
		12.6	23.0
		16.8	26.1
		24.4	36.5
		27.0	38.6
48.1	66.6		
		4.2	11.5
		8.4	17.9
		16.8	29.5
		27.0	37.8
		33.7	46.6
		39.6	55.7
		48.1	66.6
59.9	79.9		
		4.2	15.0
		8.4	28.2
		16.8	36.4
		27.0	68.0
		43.8	71.1
		56.5	75.1
		59.9	79.9
81.8	106.1		
		4.2	12.7
		12.6	30.3
		27.0	49.3
		56.5	88.0
		59.9	100.3
		73.4	103.0
		81.8	106.1
98.7	124.8		
		4.2	22.1
		12.6	30.6
		27.0	56.0
		56.5	90.5
		73.4	112.6
		90.3	113.9
		98.7	124.8
115.6	143.5		
		4.2	17.9
		12.6	32.4
		27.0	67.3
		56.5	98.8
		81.8	127.0
		107.1	142.0
		115.6	143.5

TABLE B18 (b)

HEMLOCK-FIR HOG FUEL (FRASER MILLS) SAMPLE # 040 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	38.6	85.5	49.6	1.73	63.5	57.50	5.84	1.42
48.1	66.6	132.9	64.0	2.07	58.7	57.50	7.55	1.83
59.9	79.9	186.2	105.3	1.77	62.8	57.50	12.41	3.01
81.8	106.1	240.3	126.1	1.91	60.9	57.50	14.86	3.60
98.7	124.8	276.8	136.2	2.03	59.2	57.50	16.05	3.89
113.6	143.5	328.0	164.2	2.00	59.7	57.50	19.35	4.69

SHEAR INDEX (N) = 1.60

YIELD LOCUS	PERCENT FIT
1	98.8
2	98.7
3	98.1
4	98.9
5	99.5
6	99.4

TABLE B18 (c)

WALL FRICTION TEST RESULTS

HEM-FIR HOG FUEL (FRASER MILLS) SAMPLE 040

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.7	36.6
68.2	32.9
59.7	29.2
51.3	25.2
43.2	21.3
34.5	17.3
26.0	13.4
17.5	9.5
9.0	5.5
4.6	3.2

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.7	40.5
68.2	36.3
59.7	32.3
51.3	28.0
42.9	23.6
34.5	19.2
26.0	15.1
17.5	10.6
9.0	6.0
4.6	3.3

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.7	19.7
68.2	17.6
59.7	15.6
51.3	13.5
42.9	11.6
34.5	9.6
26.0	7.5
17.5	5.5
9.0	3.3
4.6	2.1

TABLE B18 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

HEMLOCK-FIR HOG FUEL SAMPLE # 040

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<---------------FLOW PROPERTIES--------------->					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS		UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
				INST	TIME				
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20 HOURS									
27.0	34.8	27.0	39.3	85.5	88.9	53.9	64.8	57.5	6.36
59.9	84.9	59.9	92.4	186.2	210.6	137.2	66.9	57.5	16.19
98.7	121.7	98.7	133.5	276.8	299.7	164.1	62.0	57.5	19.37
CONSOLIDATION PERIOD 102 HOURS									
48.1	63.3	48.1	75.8	132.9	173.4	116.1	67.7	57.5	13.70
CONSOLIDATION PERIOD 160 HOURS									
59.9	84.9	59.9	92.4	186.2	210.6	137.2	66.9	57.5	16.19

SHEAR INDEX (N) = 1.60

COHESION/ TENSILE
STRENGTH = 4.11

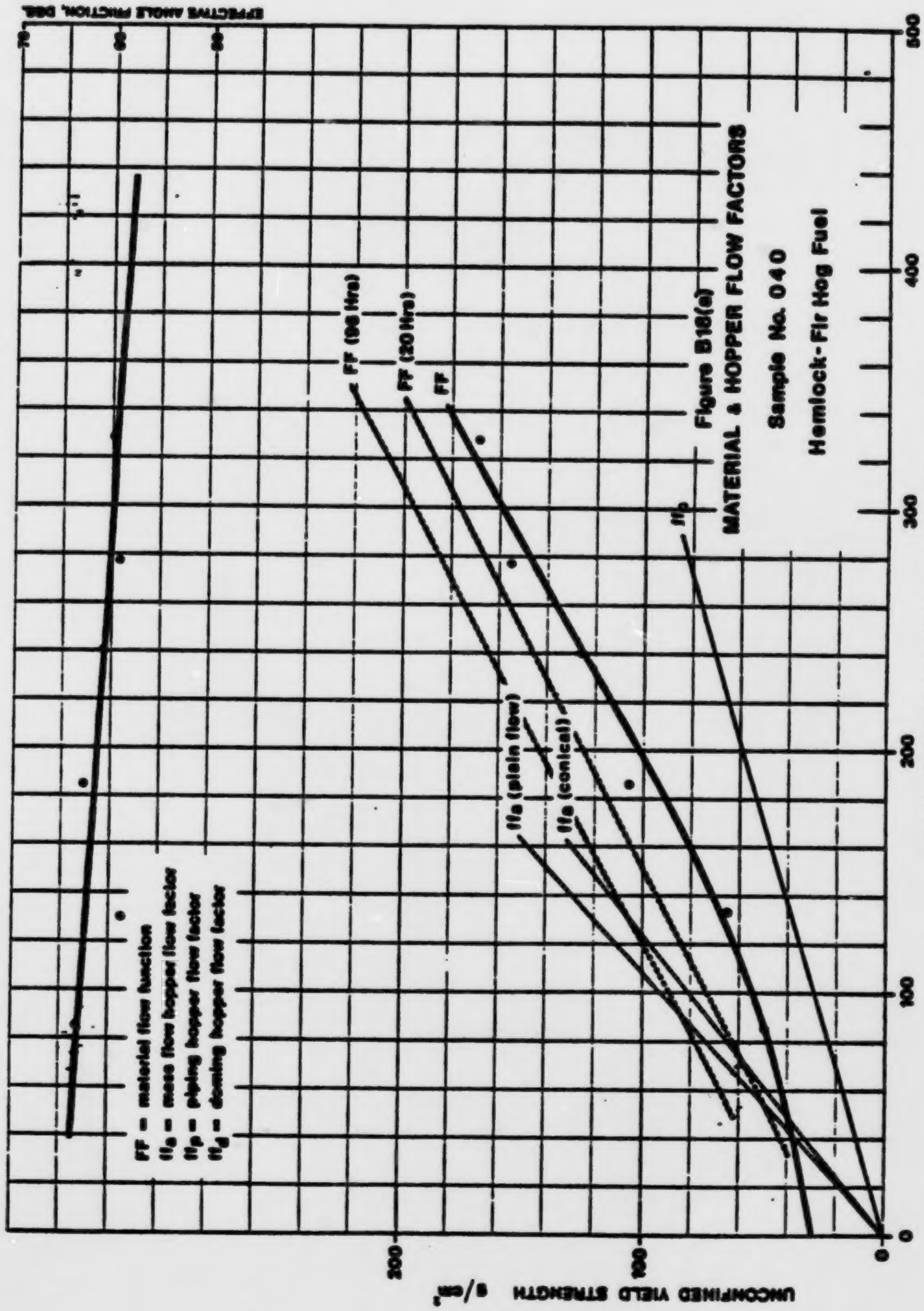

Figure B16(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 040
Hemlock-Fir Hog Fuel

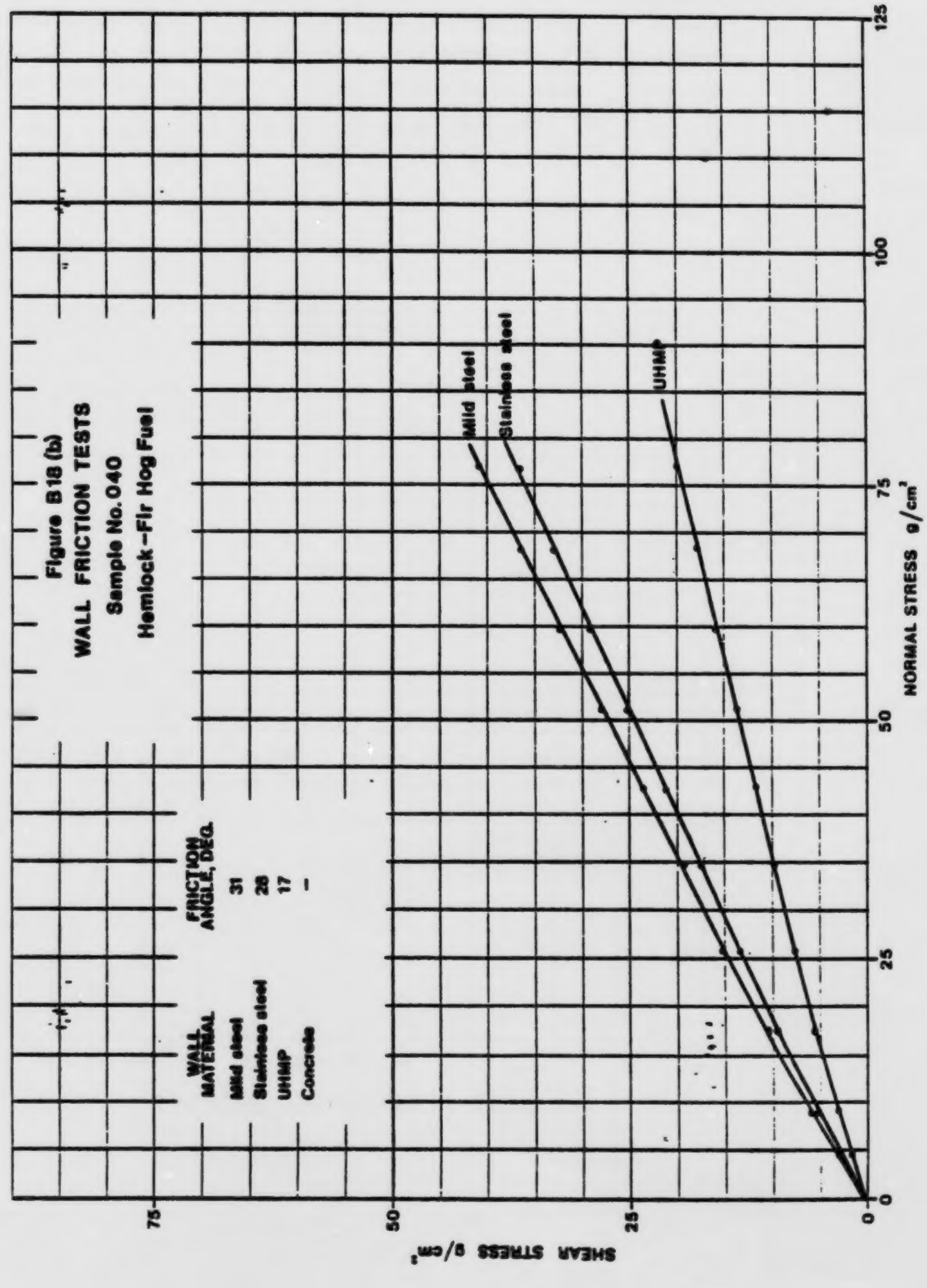

Figure B18 (b)
WALL FRICTION TESTS
Sample No. 040
Hemlock-Fir Hog Fuel

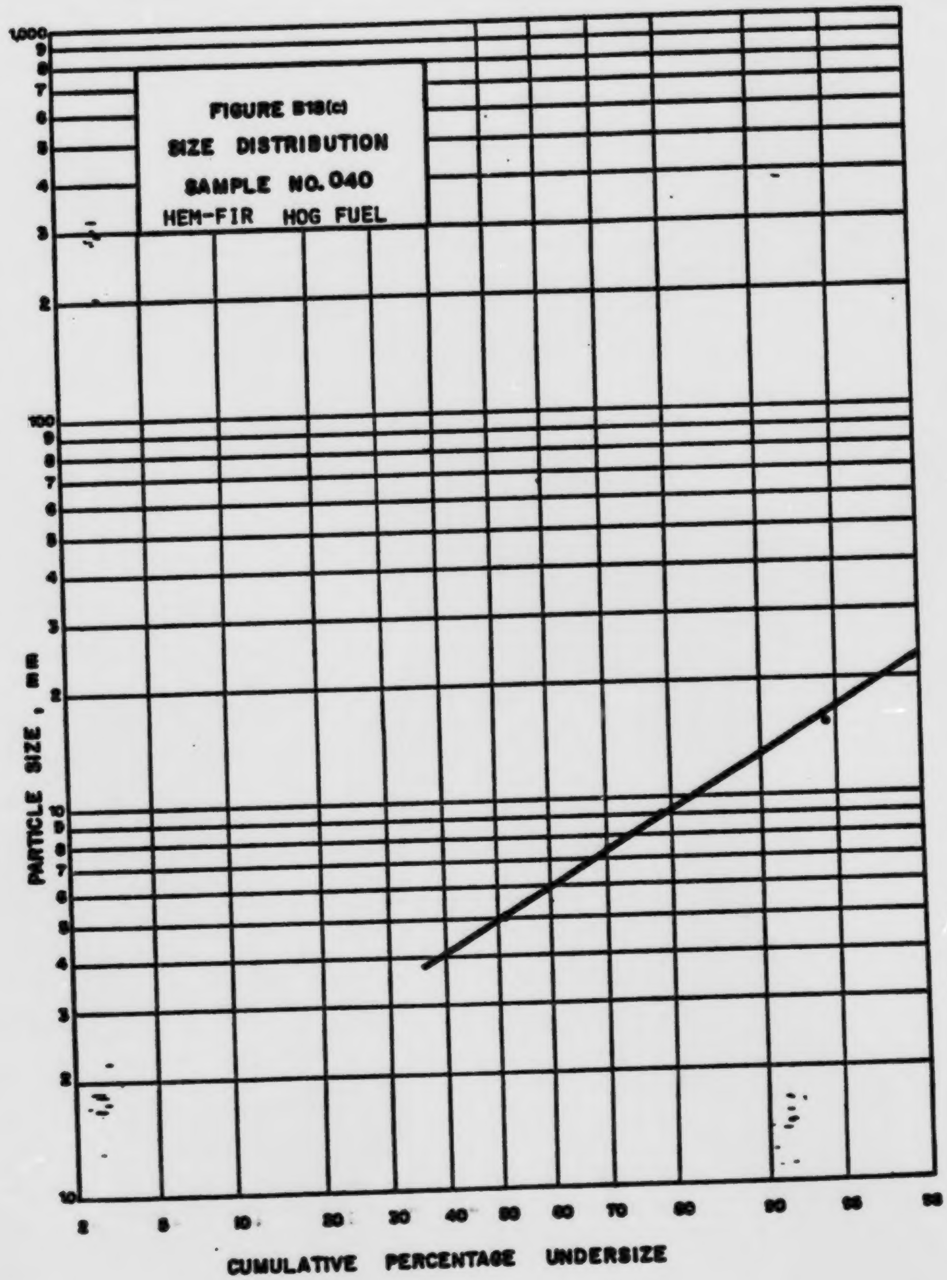

FIGURE B18(c)
SIZE DISTRIBUTION
SAMPLE NO. 040
HEM-FIR HOG FUEL

TABLE B19 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEM-FIR HOG FUEL (FRASER MILLS) SAMPLE # 040-C

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	46.5		
		2.5	6.8
		4.2	13.1
		8.4	17.2
		12.6	24.7
		16.8	29.3
		24.4	37.6
		27.0	46.5
48.1	72.6		
		4.2	9.4
		8.4	19.5
		16.8	29.6
		27.0	41.8
		33.7	57.1
		39.6	60.2
		48.1	72.6
59.9	76.3		
		4.2	15.2
		8.4	19.9
		16.8	31.8
		27.0	46.2
		43.8	63.3
		56.5	71.8
		59.9	76.3
81.8	117.0		
		4.2	28.1
		12.6	45.1
		27.0	47.7
		56.5	88.5
		59.9	97.3
		73.4	114.2
		81.8	117.0
98.7	150.4		
		4.2	20.5
		12.6	54.8
		27.0	77.4
		56.5	92.4
		73.4	96.8
		90.3	130.4
		98.7	150.4
115.6	165.4		
		4.2	25.6
		12.6	35.9
		27.0	84.6
		56.5	105.3
		81.8	122.0
		107.1	153.5
		115.6	165.4

TABLE B19 (b)

HEM-FIR HOG FUEL (FRASER MILLS) SAMPLE # 040-C (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	46.5	98.4	44.7	2.20	63.5	62.54	4.62	1.11
48.1	72.6	157.8	61.6	2.56	60.6	62.54	6.37	1.53
59.9	76.3	175.7	57.1	3.08	57.3	62.54	5.91	1.42
81.8	117.0	278.1	114.4	2.43	61.6	62.54	11.83	2.85
98.7	150.4	331.0	133.4	2.48	61.2	62.54	13.80	3.32
115.6	165.4	385.1	153.7	2.51	61.0	62.54	15.90	3.83

SHEAR INDEX (N) = 1.47

YIELD LOCUS	PERCENT FIT
1	98.8
2	98.9
3	99.9
4	99.3
5	98.1
6	99.2

TABLE B19 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

HEM-FIR HOG FUEL SAMPLE # 040-C

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<---------------FLOW PROPERTIES--------------->					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS INST	TIME	UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20 HOURS									
48.1	64.5	48.1	89.2	157.8	224.5	135.2	69.5	62.8	13.90
81.8	103.8	81.8	183.1	278.1	490.6	378.6	75.6	62.8	38.91
98.7	128.5	98.7	186.0	331.0	469.9	289.1	70.0	62.8	29.71
115.6	136.3	115.6	245.5	385.1	645.8	467.1	73.9	62.8	48.00
115.6	136.3	115.6	249.6	385.1	660.2	487.5	74.4	62.8	50.10
CONSOLIDATION PERIOD 90 HOURS									
59.9	101.5	59.9	171.6	175.7	224.5	135.2	69.5	62.8	13.90

SHEAR INDEX (N) = 1.47

COHESION/ TENSILE
STRENGTH = 4.16

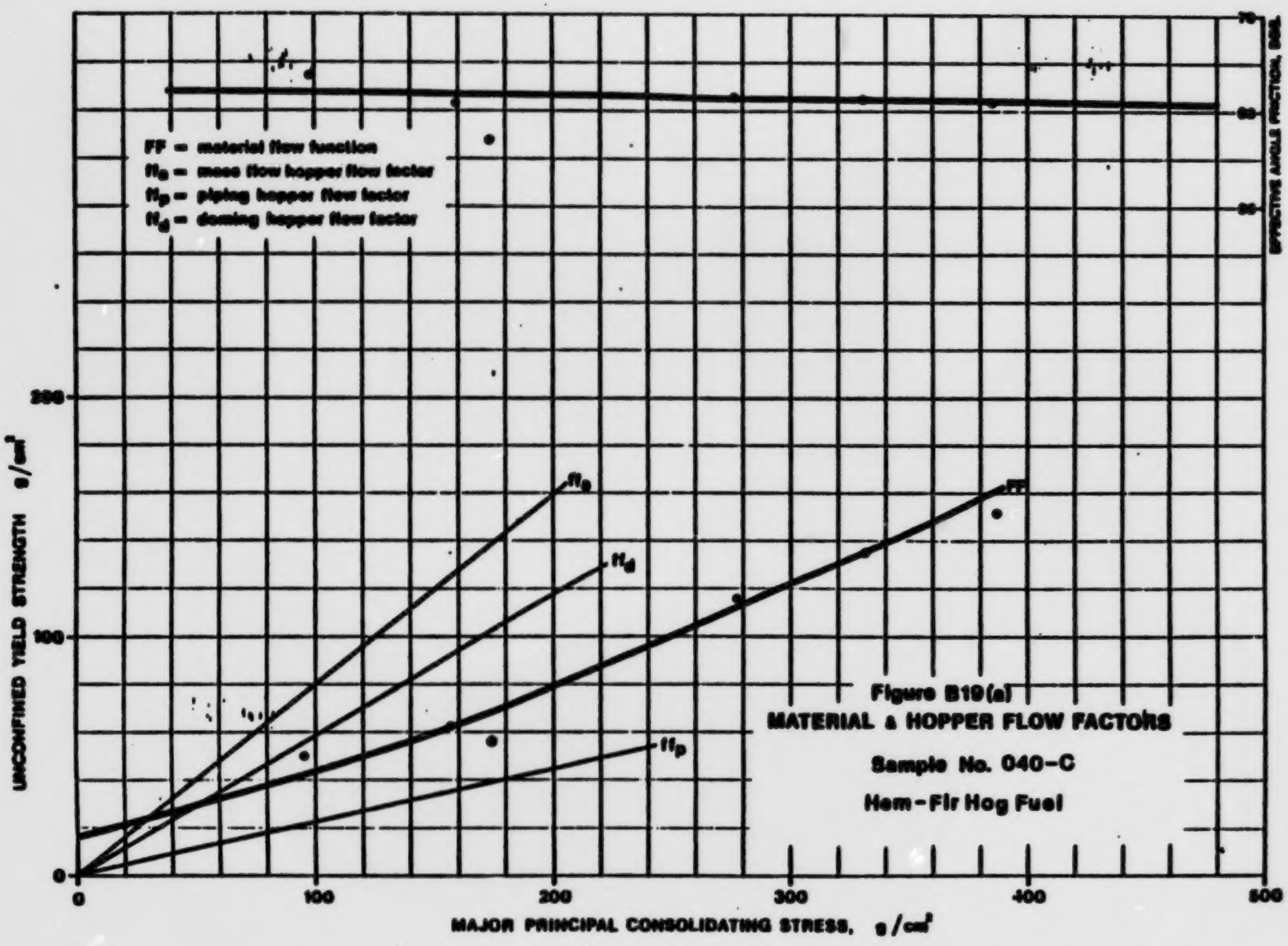

Figure B19(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 040-C
Hem-Fir Hog Fuel

TABLE B20 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

RED CEDAR CHIPS (MB - WHITE PINE DIVISION) SAMPLE # 001

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
60.8	98.6		
		2.5	5.8
		4.2	9.4
		8.4	18.7
		18.6	39.9
		35.4	53.7
		43.9	76.1
		60.8	98.6
73.4	106.1		
		2.5	8.1
		4.2	8.7
		8.4	17.2
		18.6	43.7
		43.9	73.0
		53.2	102.3
		73.4	106.1
90.3	135.7		
		2.5	8.1
		5.9	13.4
		18.6	39.3
		35.4	88.6
		53.2	104.2
		73.4	116.7
		90.3	135.7
104.2	202.8		
		2.5	12.5
		8.4	23.1
		27.0	66.1
		53.2	99.8
		73.4	124.8
		98.7	159.1
		104.2	202.8

TABLE B20 (b)

RED CEDAR CHIPS (MB - WHITE PINE DIVISION) SAMPLE # 001 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
60.8	98.6	252.1	27.4	9.22	60.0	68.28	2.43	.66
73.4	106.1	303.9	32.8	9.26	59.9	68.28	2.92	.79
90.3	135.7	386.8	45.8	8.44	60.6	68.28	4.08	1.10
104.2	202.8	491.5	74.7	6.58	62.5	68.28	6.65	1.80

SHEAR INDEX (N) = 1.24

YIELD LOCUS	PERCENT FIT
1	99.2
2	98.5
3	98.3
4	98.7

TABLE B20 (c)

WALL FRICTION TEST RESULTS

RED CEDAR CHIPS (MB - WHITE PINE DIV.) SAMPLE 001

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	39.4
66.7	34.4
58.2	30.3
49.8	25.8
41.3	21.7
32.9	17.4
24.4	13.3
15.9	8.4
7.4	3.8
3.1	1.1

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	43.0
66.7	38.7
58.2	33.7
49.8	28.7
41.3	24.0
32.9	19.0
24.4	14.0
15.9	9.5
7.4	4.1
3.1	1.4

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	14.9
66.7	13.7
58.2	12.2
49.8	10.2
41.3	9.0
32.9	7.3
24.4	5.7
15.9	3.8
7.4	2.0
3.1	.9

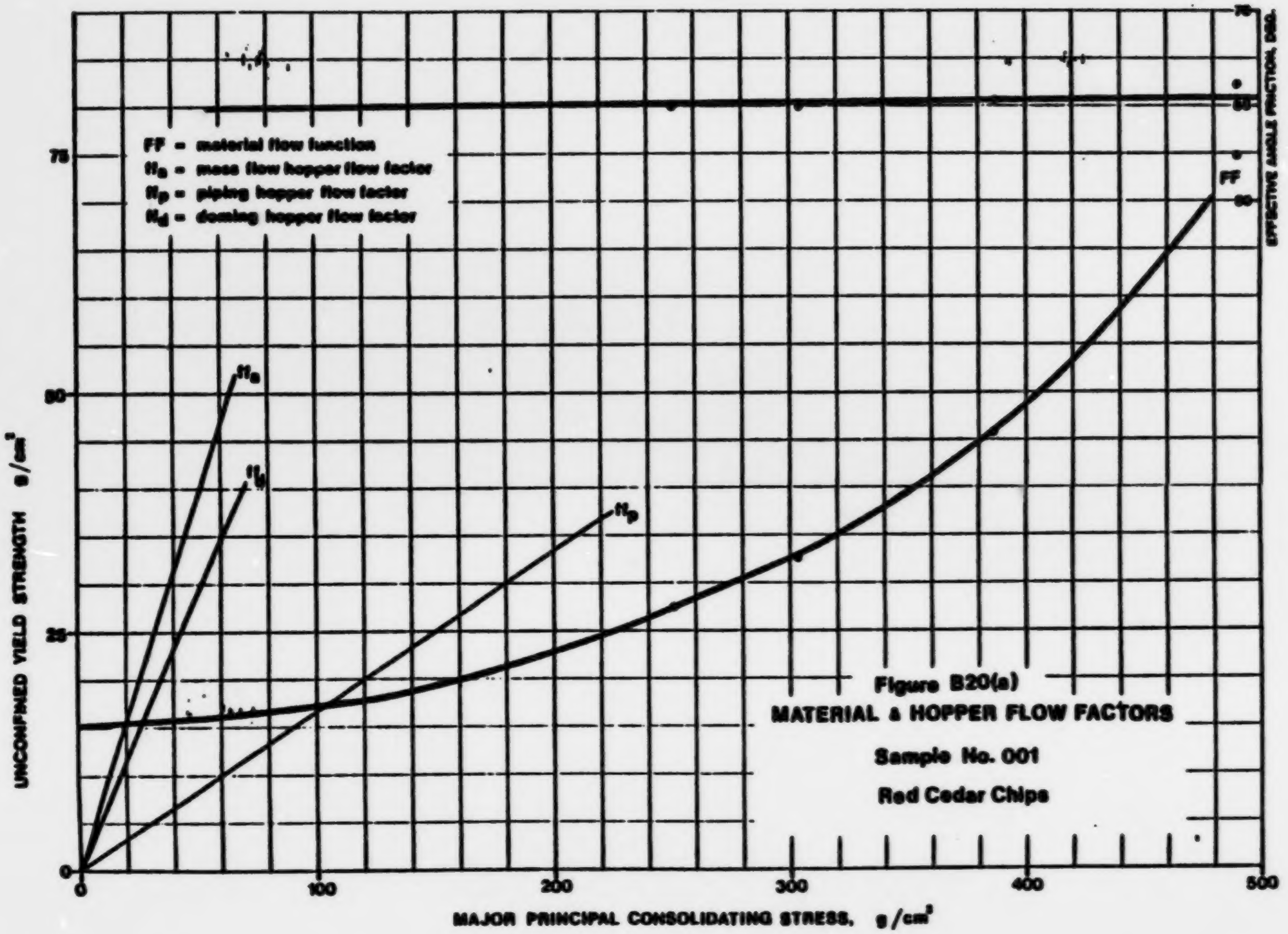

Figure B20(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 001
Red Cedar Chips

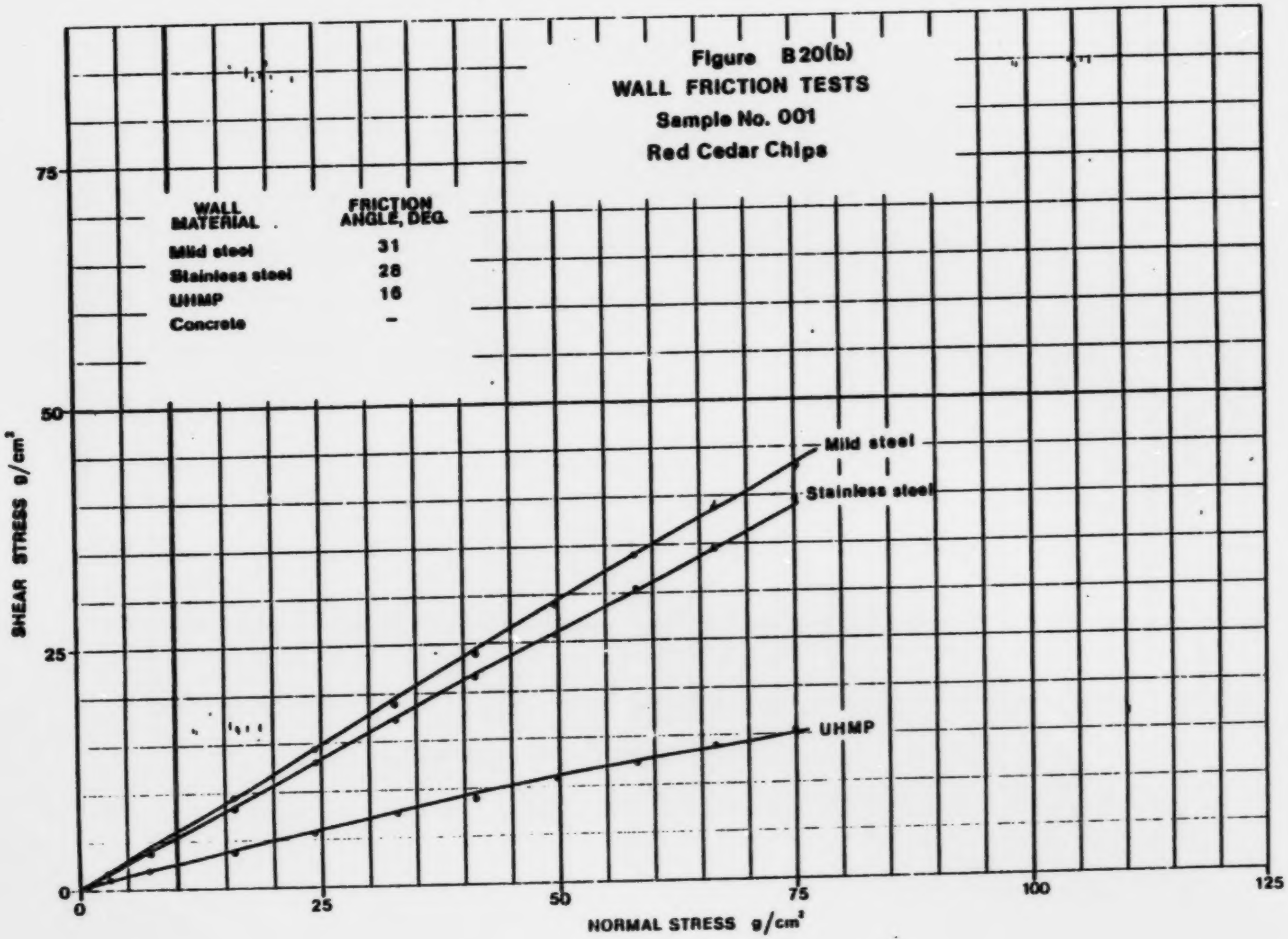

Figure B20(b)
WALL FRICTION TESTS
Sample No. 001
Red Cedar Chips

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	31
Stainless steel	28
UHMP	16
Concrete	-

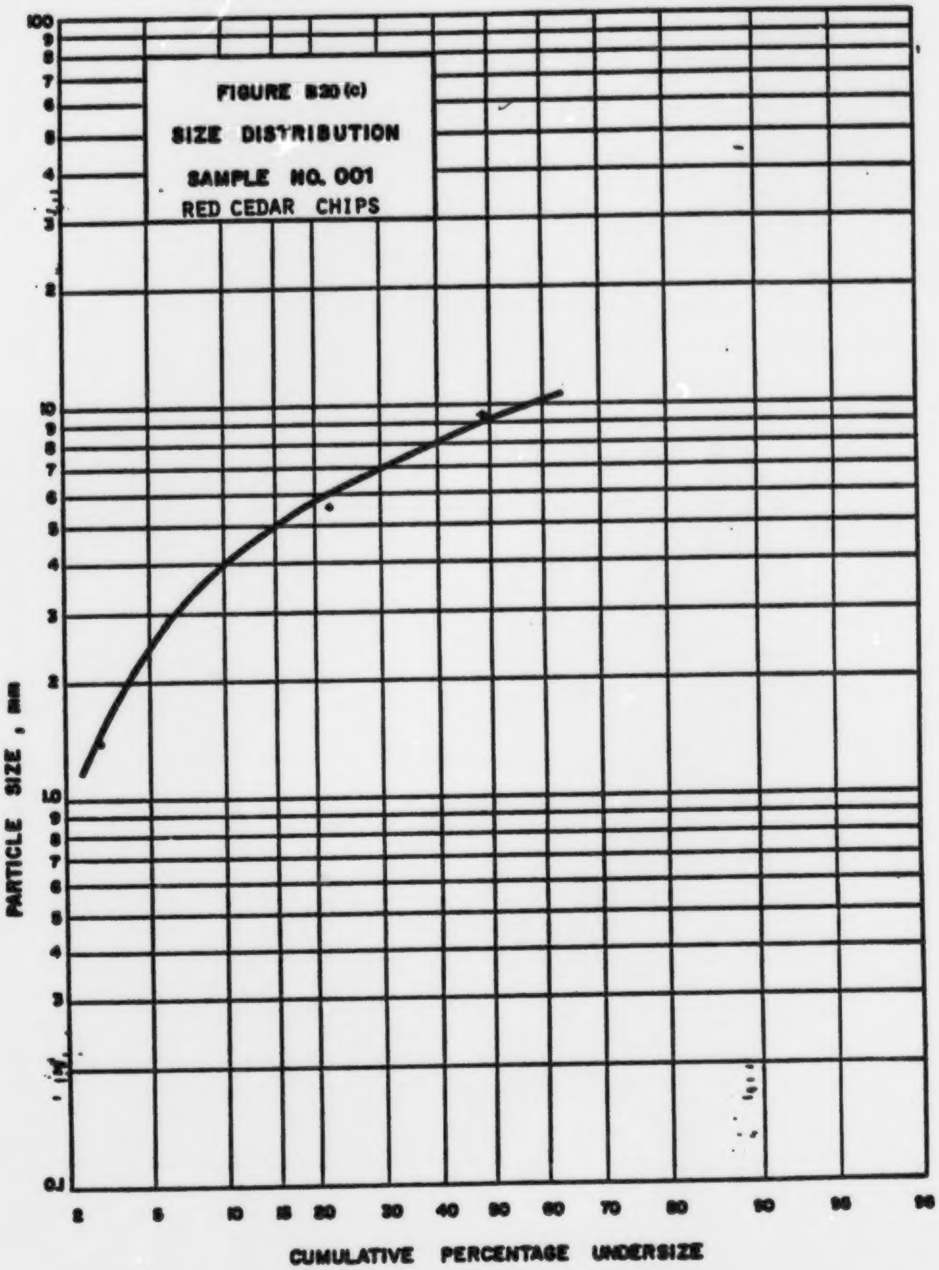
FIGURE B20(c)
SIZE DISTRIBUTION
SAMPLE NO. 001
RED CEDAR CHIPS
PARTICLE SIZE, mm
CUMULATIVE PERCENTAGE UNDERSIZE
100
10
1.0
0.1
2
5
10
15
20
30
40
50
60
70
80
90
95
98

TABLE B21 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

RED CEDAR CHIPS (MB - WHITE PINE DIVISION) SAMPLE # 002

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
56.5	81.1		
		2.5	9.4
		4.2	10.3
		8.4	18.7
		18.6	36.8
		35.4	51.8
		43.9	69.9
		56.5	81.1
73.4	107.3		
		2.5	8.4
		4.2	10.3
		8.4	18.1
		18.6	48.7
		43.9	68.6
		53.2	73.6
		73.4	107.3
90.3	124.8		
		4.2	11.7
		5.9	19.5
		18.6	39.0
		35.4	64.9
		53.2	83.6
		73.4	108.6
		90.3	124.8
115.6	156.0		
		4.2	17.3
		8.4	21.1
		27.0	57.1
		53.2	93.0
		73.4	106.1
		98.7	149.8
		115.6	156.0
144.3	196.6		
		4.2	22.2
		8.4	28.1
		35.4	93.6
		73.4	148.2
		98.7	162.2
		125.8	196.6
		144.3	196.6

TABLE B21 (b)

RED CEDAR CHIPS (MB - WHITE PINE DIVISION) SAMPLE # 002 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
56.5	81.1	193.5	47.1	4.11	58.7	64.43	4.76	1.29
73.4	107.3	247.5	58.4	4.24	58.3	64.43	5.90	1.60
90.3	124.8	302.2	70.2	4.31	58.1	64.43	7.09	1.92
115.6	156.0	384.4	88.0	4.37	57.9	64.43	8.90	2.41
144.3	196.6	527.7	146.0	3.61	60.3	64.43	14.76	3.99

SHEAR INDEX (N) = 1.35

YIELD LOCUS	PERCENT FIT
1	99.5
2	98.7
3	99.9
4	99.6
5	99.2

TABLE B21 (c)

WALL FRICTION TEST RESULTS

RED CEDAR CHIPS SAMPLE #002

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.4	39.4
66.9	35.8
58.4	30.5
50.0	26.0
41.5	21.7
33.1	17.9
24.6	13.6
16.1	9.3
7.6	4.8
3.3	2.3

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.4	43.0
66.9	38.7
58.4	33.7
50.0	28.9
41.5	24.0
33.1	19.0
24.6	14.3
16.1	9.7
7.6	5.0
3.3	2.0

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.4	16.7
66.9	14.7
58.4	12.9
50.0	11.3
41.5	9.7
33.1	7.9
24.6	6.1
16.1	4.3
7.6	2.3
3.3	1.2

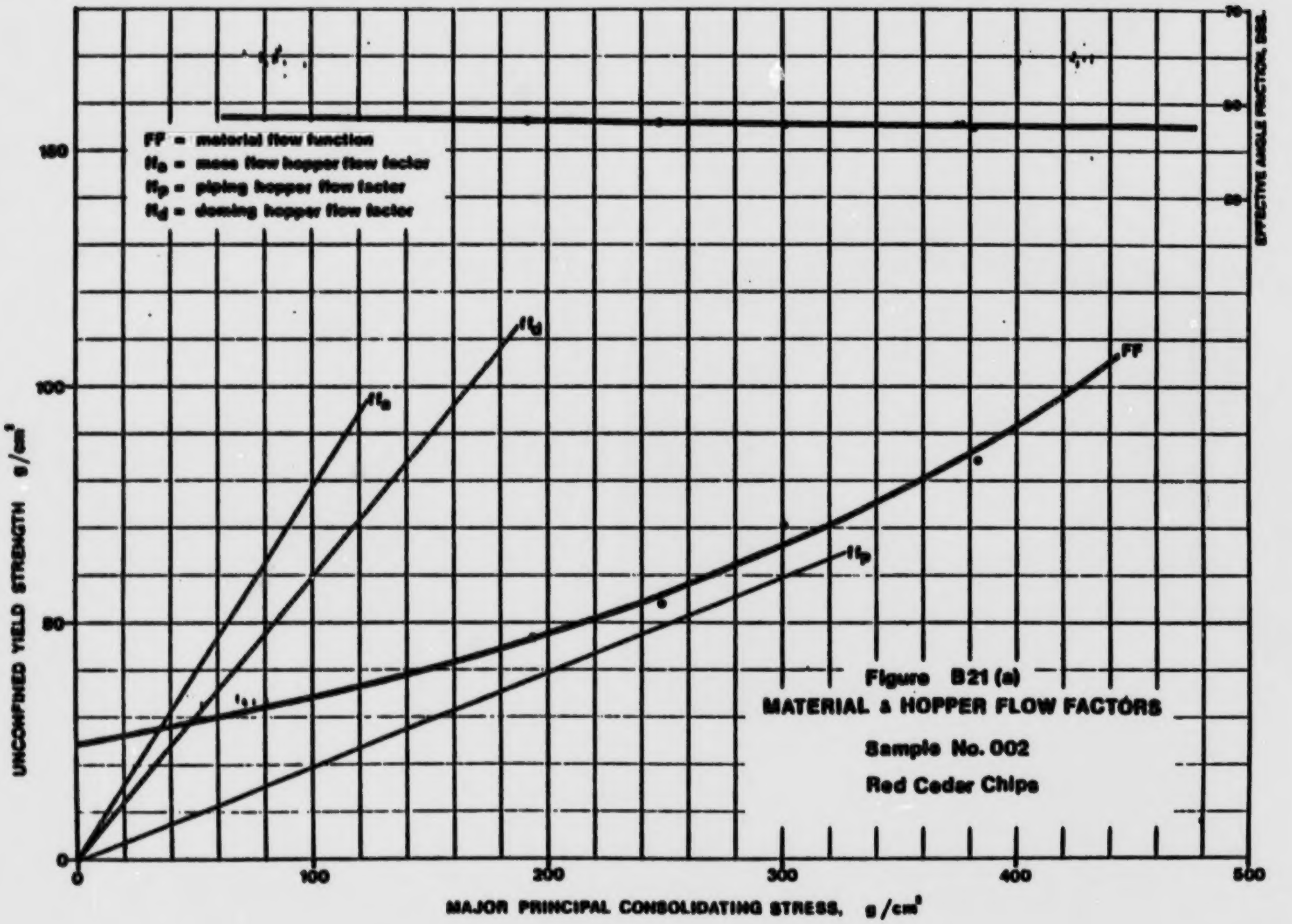

Figure B21 (a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 002
Red Cedar Chips

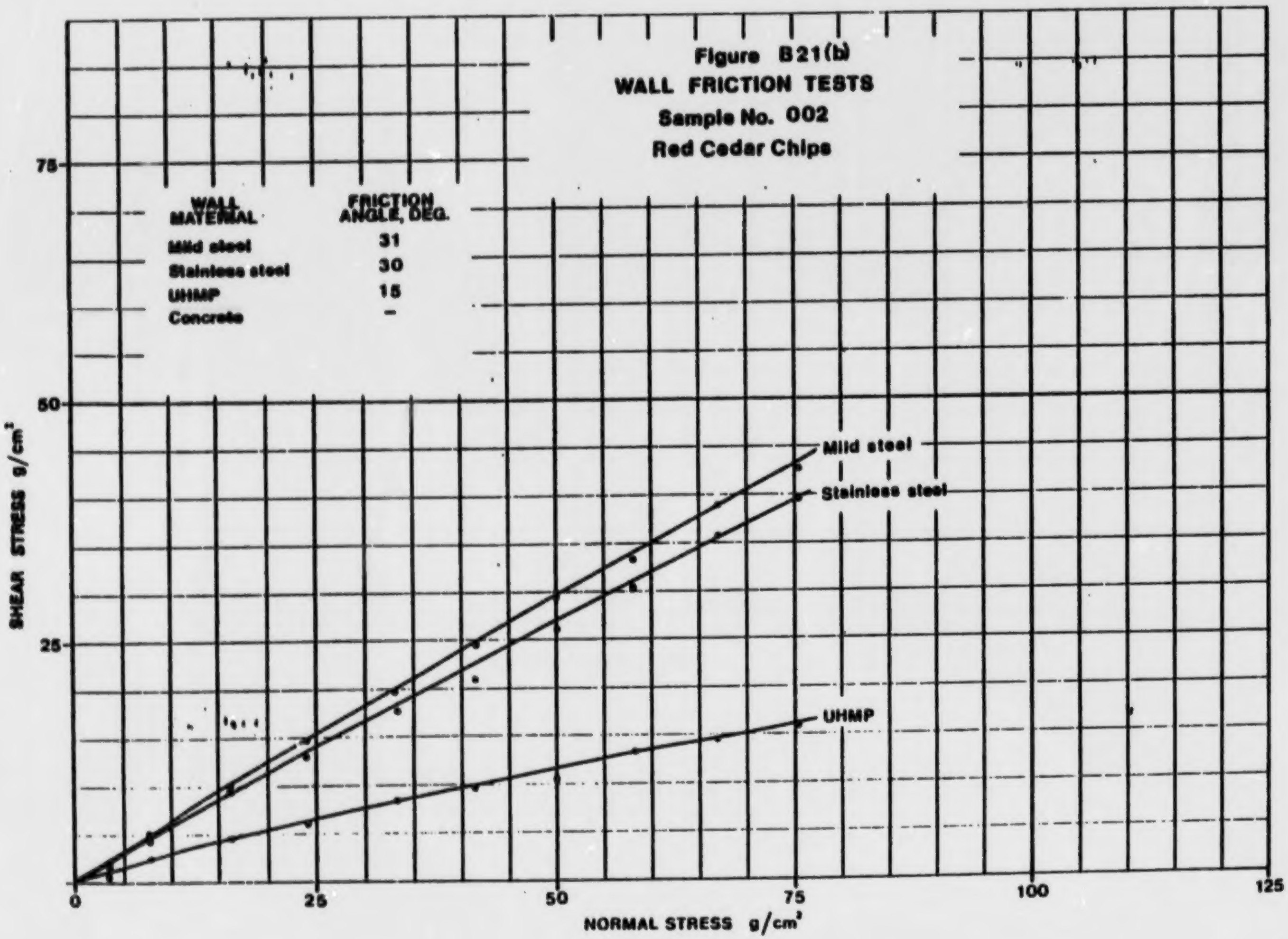

Figure B21(b)
WALL FRICTION TESTS
Sample No. 002
Red Cedar Chips

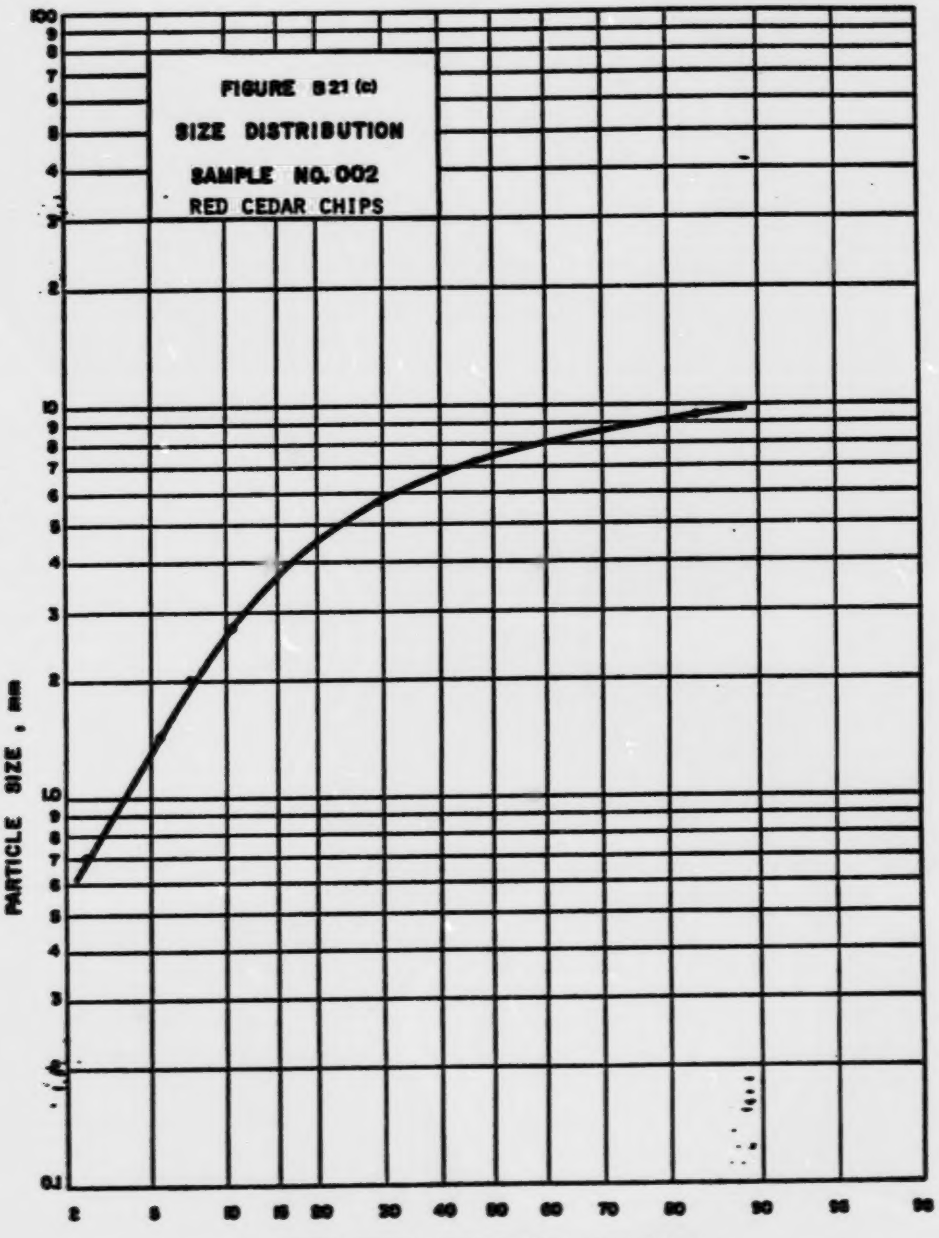
FIGURE B21 (c)
SIZE DISTRIBUTION
SAMPLE NO. 002
RED CEDAR CHIPS
PARTICLE SIZE , mm
CUMULATIVE PERCENTAGE UNDERSIZE
100
9
8
7
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1.0
9
8
7
6
5
4
3
2
0.1
2
5
10
15
20
30
40
50
60
70
80
90
95
98

TABLE B22 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

RED CEDAR CHIPS (MB - WHITE PINE DIVISION) SAMPLE # 003

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
56.5	76.8		
		2.5	8.1
		4.2	10.0
		8.4	23.4
		18.6	30.3
		35.4	54.9
		43.9	64.9
		56.5	76.8
73.4	102.3		
		2.5	6.2
		4.2	19.3
		8.4	21.2
		18.6	38.4
		43.9	77.4
		53.2	78.6
		73.4	102.3
90.3	121.7		
		4.2	10.0
		8.4	25.0
		18.6	41.8
		35.4	53.7
		53.2	92.4
		73.4	99.8
		90.3	121.7
115.6	152.9		
		4.2	17.5
		8.4	32.8
		27.0	57.4
		53.2	89.9
		73.4	134.2
		98.7	143.5
		115.6	152.9
144.3	191.9		
		4.2	15.0
		8.4	23.1
		35.4	74.9
		73.4	124.8
		98.7	156.0
		125.8	176.3
		144.3	191.9

TABLE B22 (b)

RED CEDAR CHIPS (MB - WHITE PINE DIVISION) SAMPLE # 003 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
56.5	76.8	182.7	45.0	4.06	57.6	63.60	4.68	1.29
73.4	102.3	248.4	67.0	3.70	58.8	63.60	6.97	1.92
90.3	121.7	289.1	69.9	4.14	57.3	63.60	7.27	2.00
115.6	152.9	392.6	106.8	3.68	58.9	63.60	11.11	3.05
144.3	191.9	472.1	119.2	3.96	57.9	63.60	12.40	3.41

SHEAR INDEX (N) = 1.37

YIELD LOCUS	PERCENT FIT
1	99.6
2	99.4
3	99.2
4	99.3
5	99.8

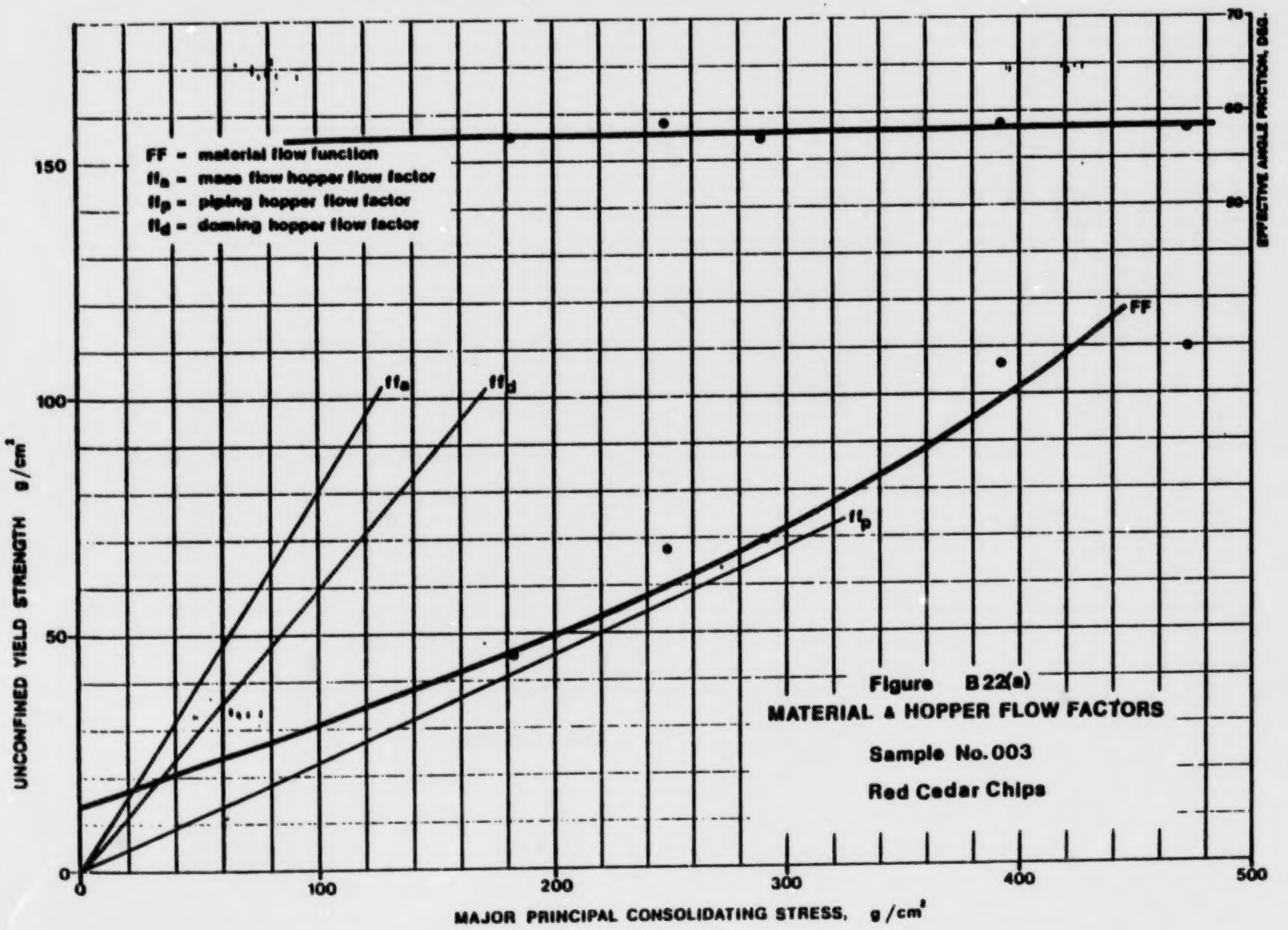

Figure B22(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 003
Red Cedar Chips

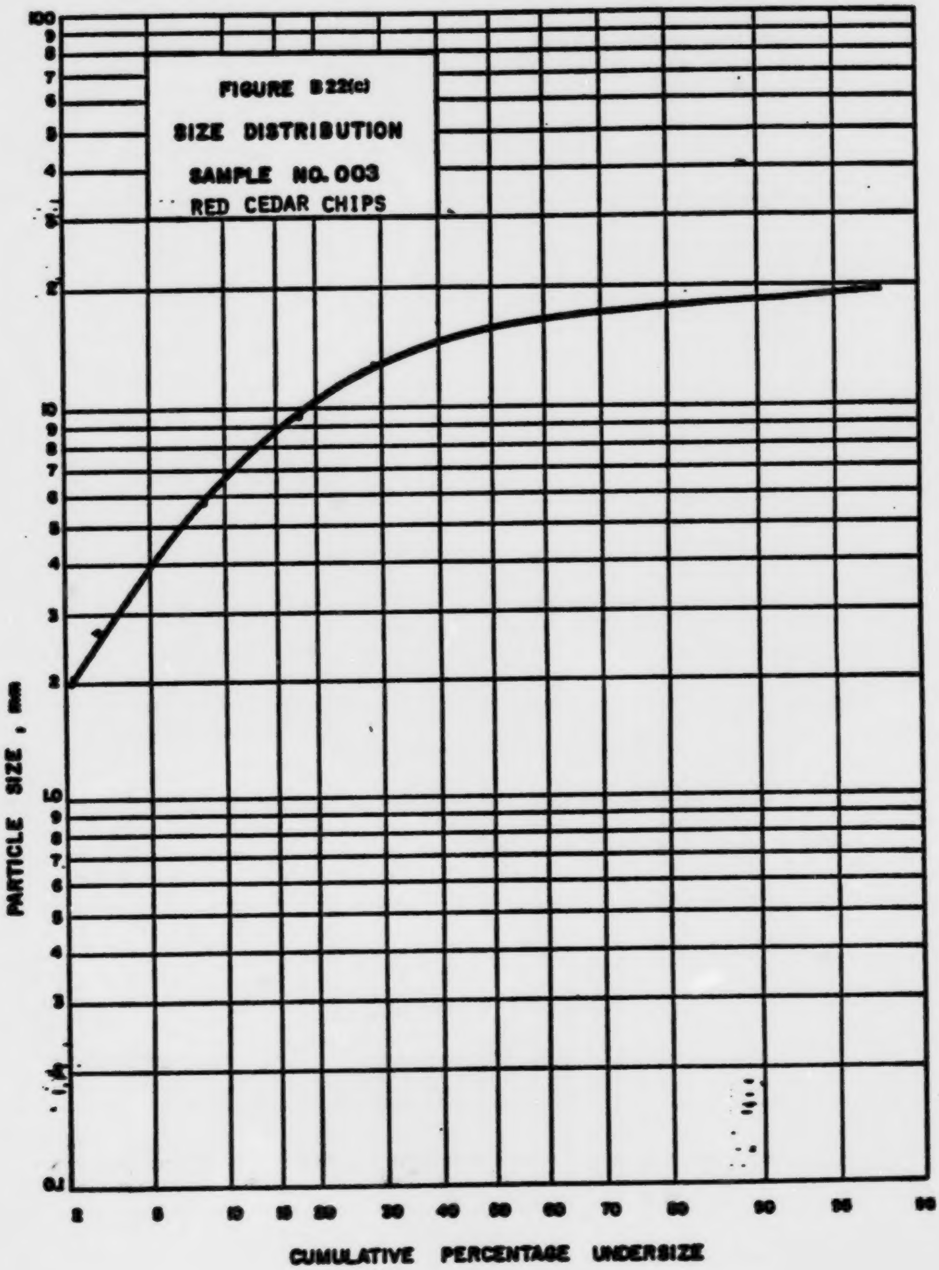

FIGURE B22(c)

SIZE DISTRIBUTION

SAMPLE NO. 003

RED CEDAR CHIPS

TABLE B23 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

RED CEDAR CHIPS SAMPLE # 004

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
56.5	80.5		
		2.5	8.7
		4.2	10.9
		8.4	20.9
		18.6	37.4
		35.4	54.9
		43.9	76.8
		56.5	80.5
73.4	104.8		
		2.5	10.2
		4.2	12.8
		8.4	19.7
		18.6	40.2
		43.9	72.4
		53.2	76.8
		73.4	104.8
90.3	118.6		
		4.2	12.5
		8.4	23.1
		18.6	42.7
		35.4	72.4
		53.2	87.4
		73.4	109.2
		90.3	118.6
115.6	162.2		
		4.2	14.0
		8.4	26.5
		27.0	68.6
		53.2	88.6
		73.4	118.6
		98.7	126.7
		115.6	162.2
144.3	190.3		
		4.2	20.3
		8.4	26.2
		35.4	77.4
		73.4	138.8
		98.7	157.9
		125.8	177.8
		144.3	190.3

TABLE B23 (b)

RED CEDAR CHIPS SAMPLE # 004 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
56.5	80.5	199.3	58.4	3.41	59.9	63.88	5.99	1.61
73.4	104.8	244.5	64.3	3.80	58.5	63.88	6.60	1.77
90.3	118.6	300.4	78.8	3.81	58.4	63.88	8.08	2.17
115.6	162.2	376.9	95.1	3.96	57.9	63.88	9.75	2.62
144.3	190.3	483.1	128.4	3.76	58.6	63.88	13.16	3.53

SHEAR INDEX (N) = 1.37

YIELD LOCUS	PERCENT FIT
1	99.1
2	99.6
3	99.5
4	99.2
5	99.6

TABLE B23 (c)

WALL FRICTION TEST RESULTS

RED CEDAR CHIPS SAMPLE #004

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	39.4
67.0	35.8
58.5	31.5
50.1	26.5
41.6	22.2
33.2	17.9
24.7	14.0
16.2	9.3
7.7	4.8
3.4	.9

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	44.4
67.0	39.8
58.5	35.1
50.0	30.1
41.6	25.4
33.2	20.8
24.7	15.8
16.2	11.1
7.7	5.7
3.4	2.2

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	18.5
67.0	16.5
58.5	14.7
50.1	12.9
41.6	11.1
33.2	9.0
24.7	7.0
16.2	3.0
7.7	2.5
3.4	.9

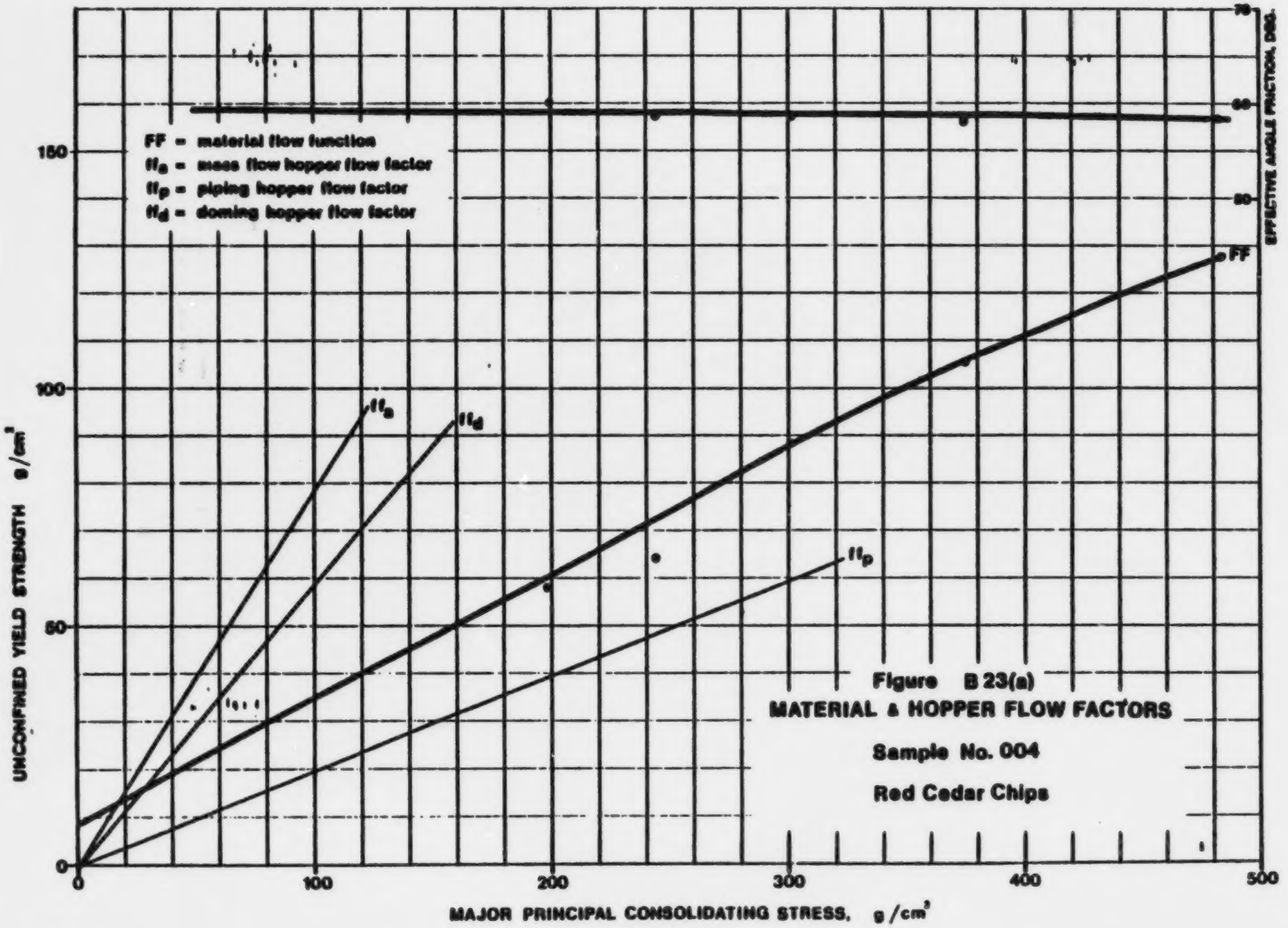

Figure B 23(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 004
Red Cedar Chips

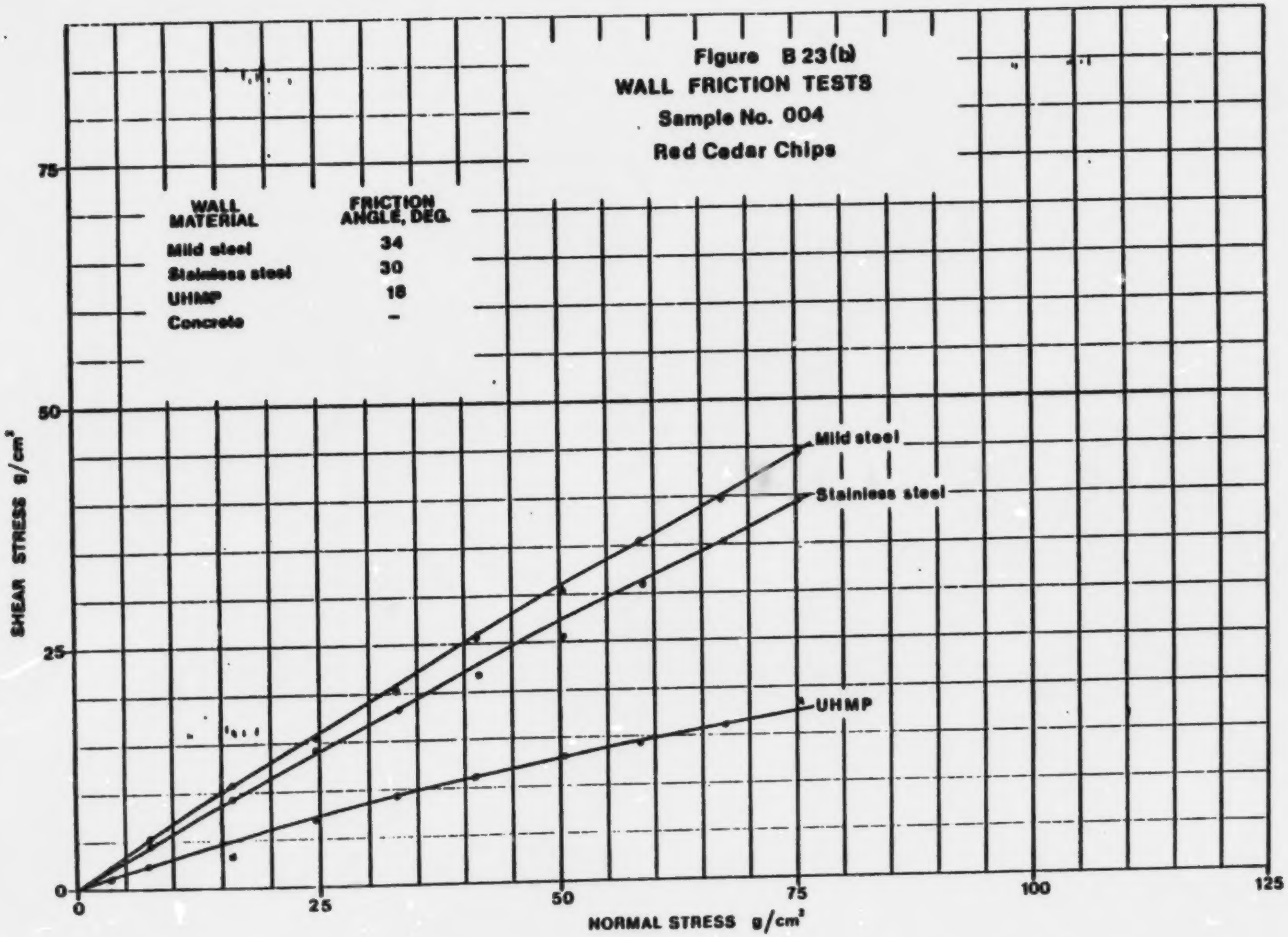

Figure B 23(b)
WALL FRICTION TESTS
Sample No. 004
Red Cedar Chips

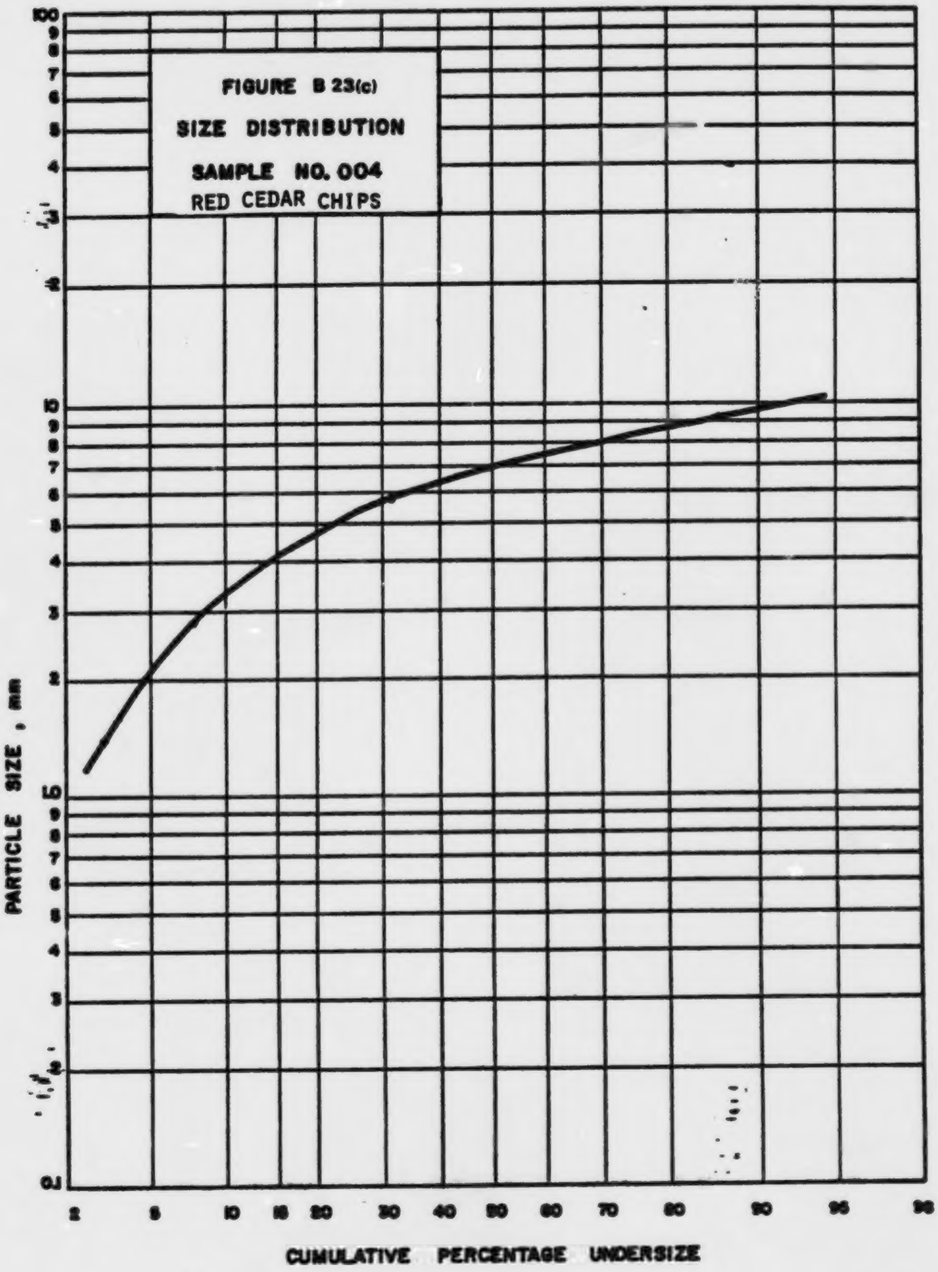

FIGURE B 23(c)

SIZE DISTRIBUTION

SAMPLE NO. 004

RED CEDAR CHIPS

TABLE B24 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK CHIPS (MB.- HARMAC) SAMPLE # 005

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
56.5	88.6		
		2.5	6.9
		4.2	10.6
		8.4	18.4
		18.6	39.0
		35.4	59.3
		43.9	67.4
		56.5	88.6
73.4	94.2		
		2.5	7.2
		4.2	13.1
		8.4	19.3
		23.2	50.2
		43.9	63.9
		53.2	76.1
		73.4	94.2
90.3	127.9		
		4.2	11.5
		8.4	18.1
		18.6	36.2
		35.4	60.5
		53.2	84.2
		73.4	96.7
		90.3	127.9
115.6	151.3		
		4.2	10.0
		8.4	18.4
		27.0	53.7
		53.2	87.4
		73.4	107.3
		98.7	146.6
		115.6	151.3
144.3	209.0		
		4.2	12.2
		8.4	25.0
		35.4	68.6
		73.4	134.2
		98.7	146.6
		125.8	171.6
		144.3	209.0

TABLE B24 (b)

HEMLOCK CHIPS (MB.- HARMAC) SAMPLE # 005 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
56.5	88.6	218.0	41.9	5.21	59.6	64.93	4.28	1.29
73.4	94.2	243.2	31.5	7.71	55.9	64.93	3.22	.97
90.3	127.9	306.4	42.4	7.23	56.5	64.93	4.33	1.31
115.6	151.3	391.1	53.7	7.28	56.5	64.93	5.49	1.65
144.3	209.0	510.8	79.1	6.46	57.6	64.93	8.08	2.44

SHEAR INDEX (N) = 1.27

YIELD LOCUS	PERCENT FIT
1	99.6
2	99.3
3	99.6
4	99.7
5	99.6

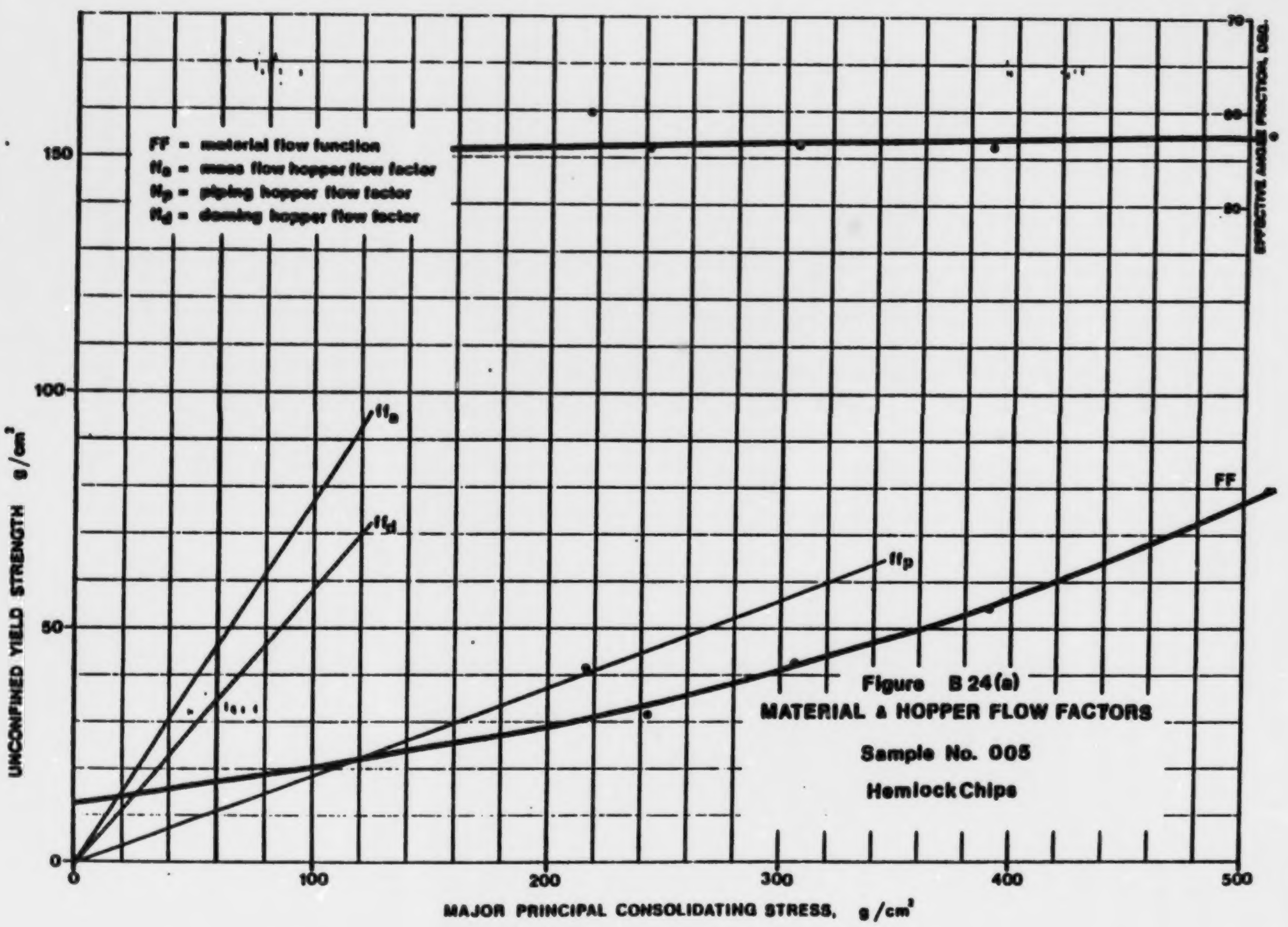

Figure B 24(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 005
Hemlock Chips

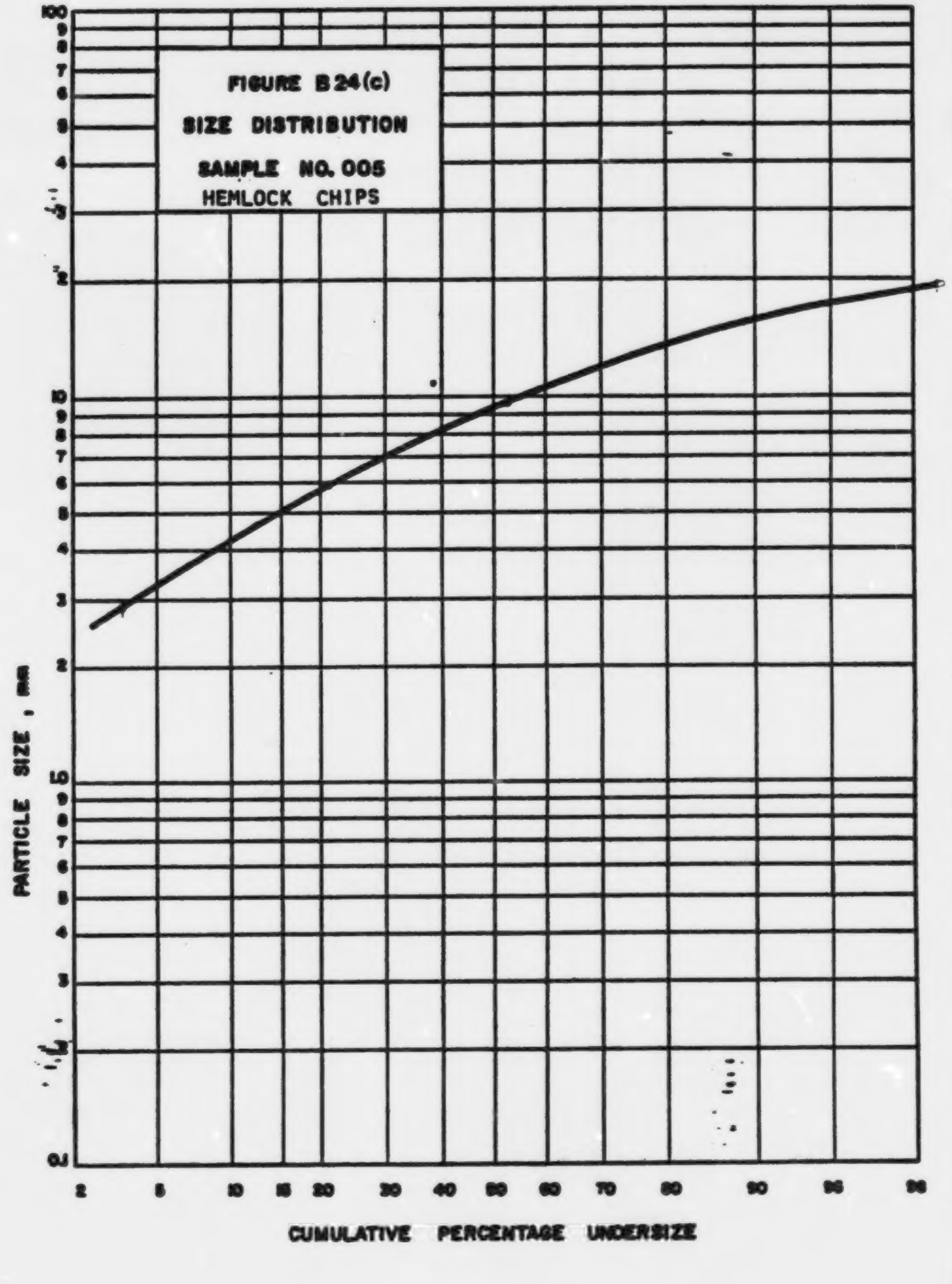
FIGURE B24(c)
SIZE DISTRIBUTION
SAMPLE NO. 005
HEMLOCK CHIPS
PARTICLE SIZE , mm
100
9
8
7
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1.0
9
8
7
6
5
4
3
2
0.1
2
5
10
15
20
30
40
50
60
70
80
90
95
98
CUMULATIVE PERCENTAGE UNDERSIZE

TABLE B25 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK CHIPS (MB - HARMAC) SAMPLE 006

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
56.5	76.1		
		2.5	6.2
		4.2	10.3
		8.4	20.0
		18.6	40.9
		35.4	55.5
		43.9	63.6
		56.5	76.1
73.4	101.4		
		2.5	5.0
		4.2	10.8
		8.4	16.4
		18.6	35.6
		43.9	64.9
		53.2	82.4
		73.4	101.4
90.3	134.2		
		4.2	10.3
		8.4	18.1
		18.6	45.2
		35.4	61.2
		53.2	93.0
		73.4	113.9
		90.3	134.2
115.6	159.1		
		4.2	10.9
		8.4	23.1
		27.0	66.1
		53.2	95.2
		73.4	120.1
		98.7	127.9
		115.6	159.1
144.3	199.7		
		4.2	9.7
		8.4	21.2
		35.4	74.9
		73.4	123.6
		98.7	151.6
		125.8	182.8
		144.3	199.7

TABLE B25 (b)

HEMLOCK CHIPS (MB - HARMAC) SAMPLE 006 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
56.5	76.1	191.2	38.2	5.00	57.6	64.56	3.89	1.10
73.4	101.4	243.3	46.5	5.24	57.1	64.56	4.73	1.34
90.3	134.2	327.8	76.6	4.28	59.4	64.56	7.79	2.20
115.6	159.1	389.5	77.3	5.04	57.5	64.56	7.87	2.23
144.3	199.7	493.4	101.1	4.88	57.9	64.56	10.30	2.91

SHEAR INDEX (N) = 1.32

YIELD LOCUS	PERCENT FIT
1	99.5
2	99.5
3	99.5
4	99.2
5	99.8

TABLE B25 (c)

WALL FRICTION TEST RESULTS

HEMLOCK CHIPS (MB - HARMAC) SCREENED TO MINUS 1/2 IN. SAMPLE 006

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	39.4
67.0	35.1
58.5	30.8
50.1	26.5
41.7	22.2
33.3	17.9
24.8	12.7
16.3	8.8
7.8	4.5
3.4	1.4

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	43.7
67.0	39.4
58.5	34.2
50.1	29.4
41.7	24.7
33.3	19.7
24.8	14.7
16.3	10.0
7.8	4.8
3.4	1.4

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.5	15.4
67.0	15.8
58.5	13.3
50.1	12.2
41.7	10.0
33.3	7.5
24.8	6.5
16.3	4.7
7.8	2.5
3.4	.7

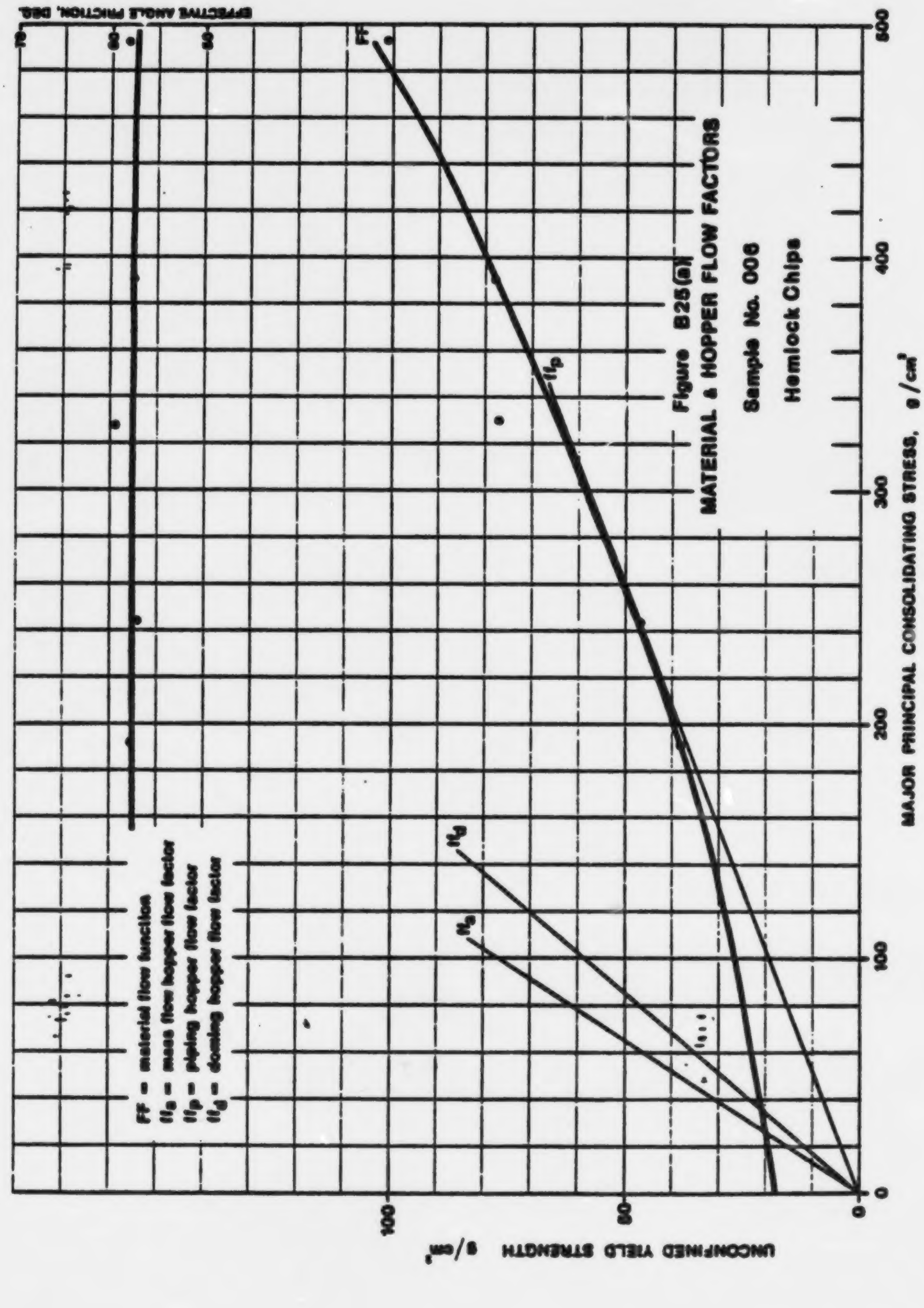

Figure B25(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 006
Hemlock Chips

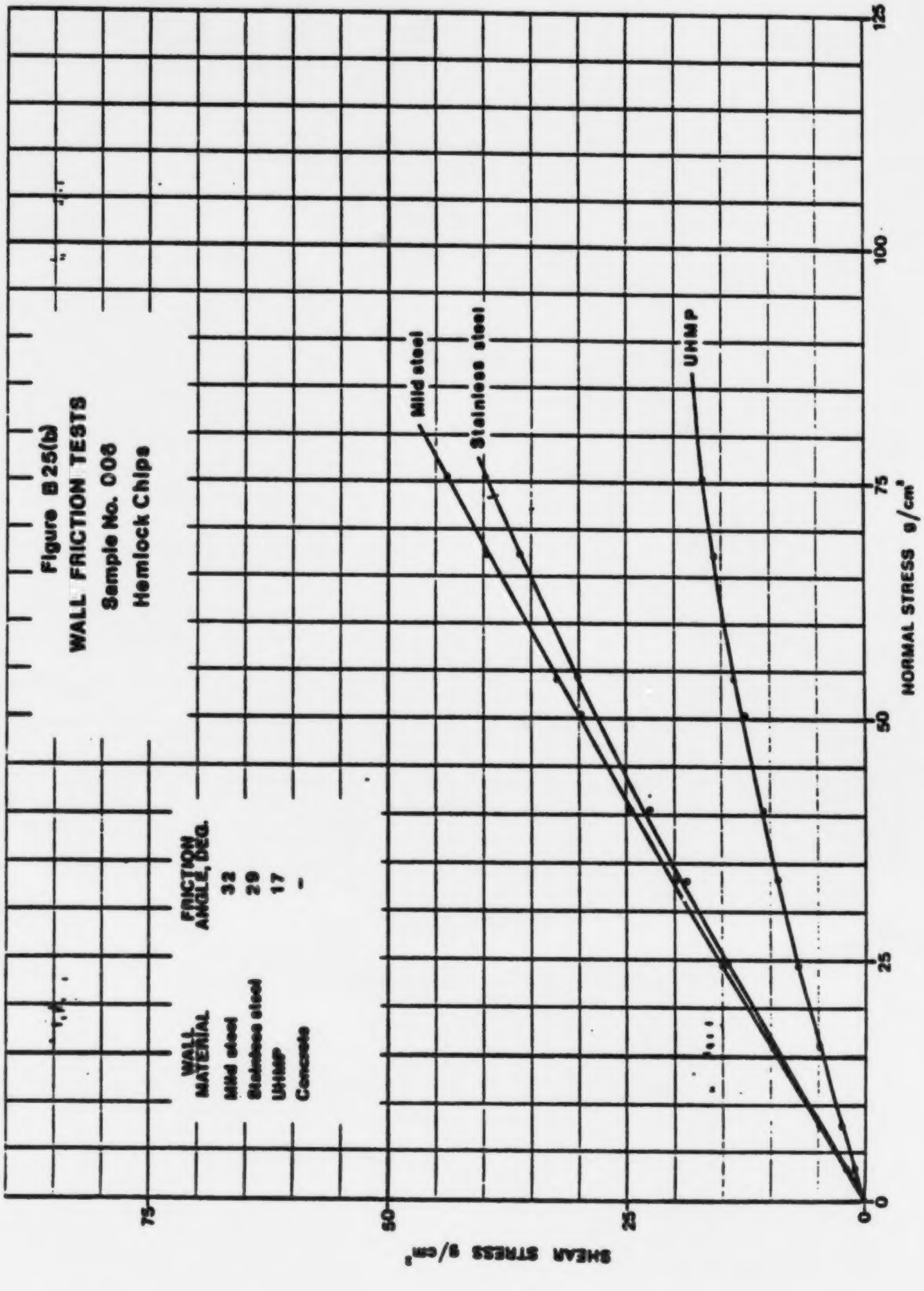

Figure B25(b)
WALL FRICTION TESTS
Sample No. 006
Hemlock Chips

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	32
Stainless steel	29
UHMP	17
Concrete	-

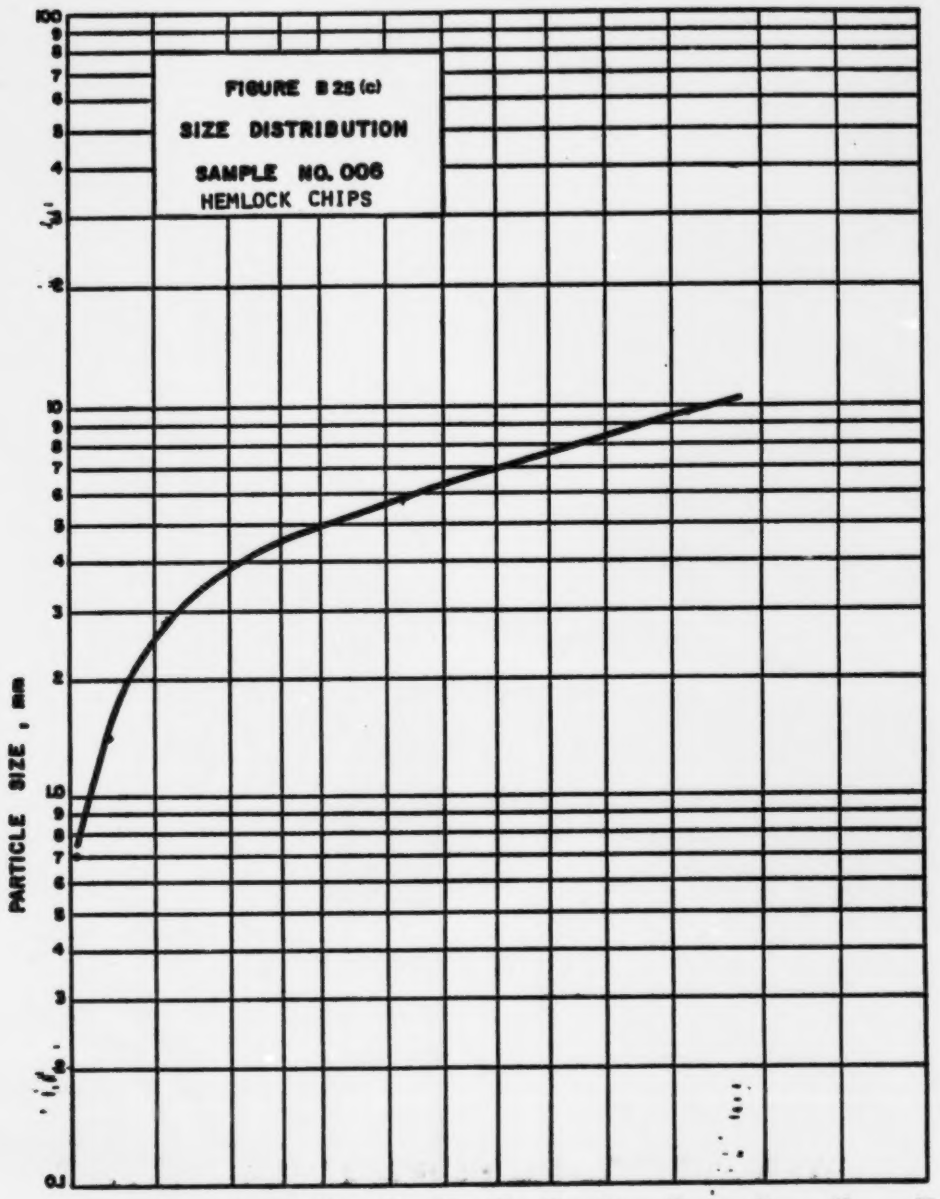

FIGURE B25(c)

SIZE DISTRIBUTION

SAMPLE NO. 006

HEMLOCK CHIPS

TABLE B26 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK CHIPS (CANFOR) SAMPLE #008

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	28.4		
		2.5	6.9
		4.2	7.2
		8.4	15.6
		12.6	19.3
		16.8	32.3
		24.4	30.0
		27.0	28.4
48.1	59.3		
		4.2	14.2
		8.4	17.9
		16.8	25.3
		27.0	45.9
		33.7	46.2
		39.5	54.3
		48.1	59.3
59.9	95.0		
		4.2	9.4
		8.4	25.8
		16.8	45.6
		27.0	51.2
		43.8	74.1
		56.5	85.5
		59.9	95.0
81.8	107.7		
		4.2	10.6
		12.6	27.3
		27.0	58.0
		56.5	85.7
		59.9	91.9
		73.4	91.9
		81.8	107.7
98.7	128.9		
		4.2	10.1
		12.6	27.5
		27.0	45.6
		56.5	82.4
		73.4	106.7
		90.3	124.8
		98.7	128.9
115.6	142.9		
		4.2	5.9
		12.6	31.7
		27.0	50.1
		56.5	101.4
		81.8	117.6
		107.1	135.7
		115.6	142.9

TABLE B26 (b)

HEMLOCK CHIPS (CANFOR) SAMPLE #008 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	28.4	77.4	20.6	3.76	55.5	62.17	2.22	.60
48.1	59.3	142.4	40.3	3.54	56.4	62.17	4.34	1.17
59.9	95.0	219.7	90.0	2.44	62.4	62.17	9.70	2.61
81.8	107.7	252.8	77.5	3.26	57.7	62.17	8.35	2.24
98.7	128.9	297.7	87.2	3.41	57.0	62.17	9.40	2.53
115.6	142.9	340.8	95.5	3.57	56.3	62.17	10.30	2.77

SHEAR INDEX (N) = 1.42

YIELD LOCUS	PERCENT FIT
1	96.2
2	99.4
3	99.3
4	99.3
5	99.4
6	99.2

TABLE B26 (c)

WALL FRICTION TEST RESULTS

HEMLOCK CHIPS (CANFOR) SAMPLE 008

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	41.2
66.7	36.6
58.2	32.0
49.7	27.6
41.3	23.3
32.9	18.6
24.4	14.3
15.9	10.4
7.4	5.0
3.1	2.4

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	44.6
66.7	39.8
58.2	35.1
49.7	30.3
41.3	25.4
32.9	20.6
24.4	15.6
15.9	10.6
7.4	5.6
3.1	2.7

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (ALONG "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	19.0
66.7	17.0
58.2	14.9
49.7	13.1
41.3	11.1
32.9	9.0
24.4	7.0
15.9	4.9
7.4	2.7
3.1	1.4

TABLE B26 (c) con't

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (ACROSS "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	23.1
66.7	20.6
58.2	18.1
49.7	15.6
41.3	13.0
32.9	10.9
24.4	8.5
15.9	5.9
7.4	3.1
3.1	1.5

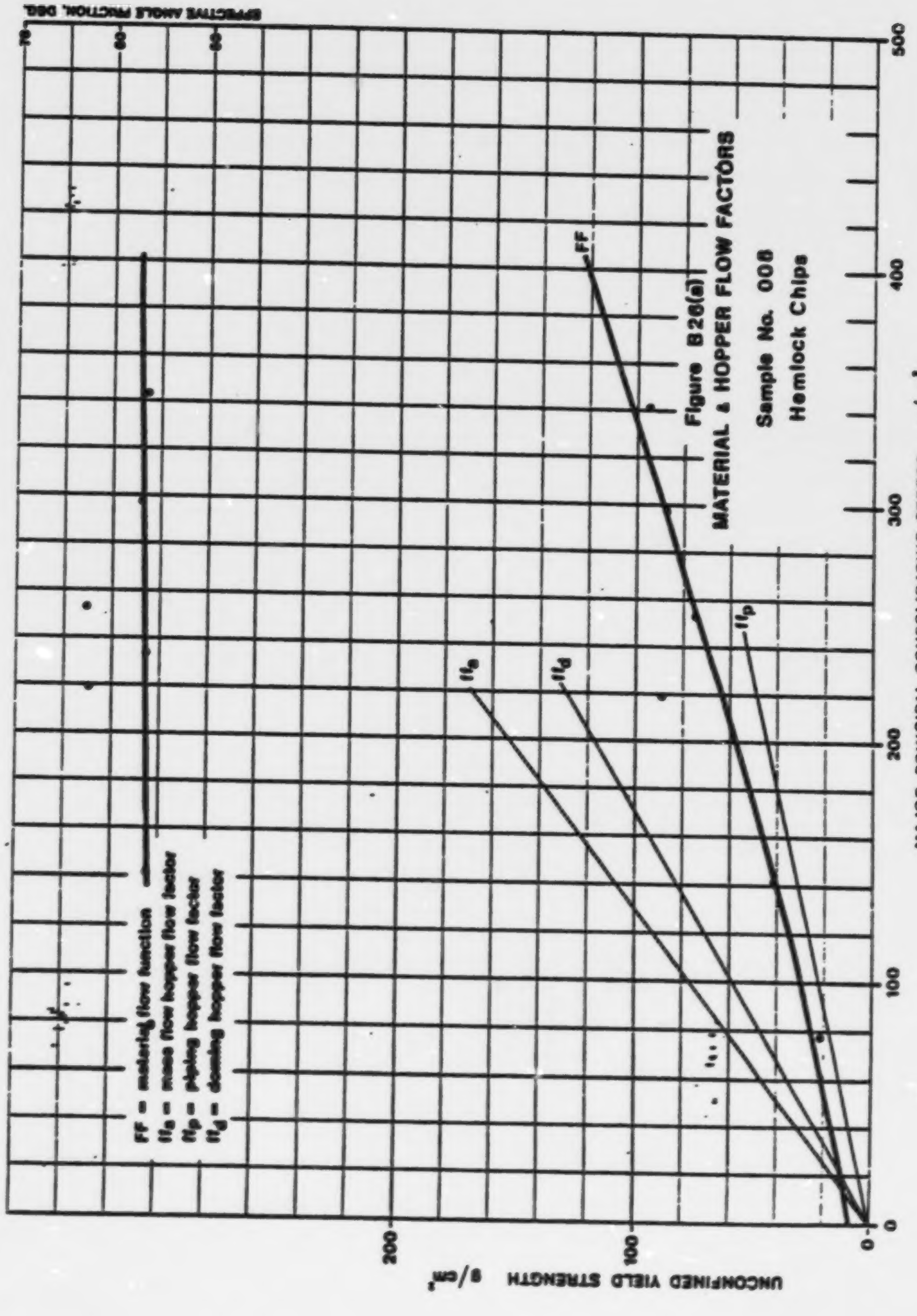

Figure B26(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 008
Hemlock Chips

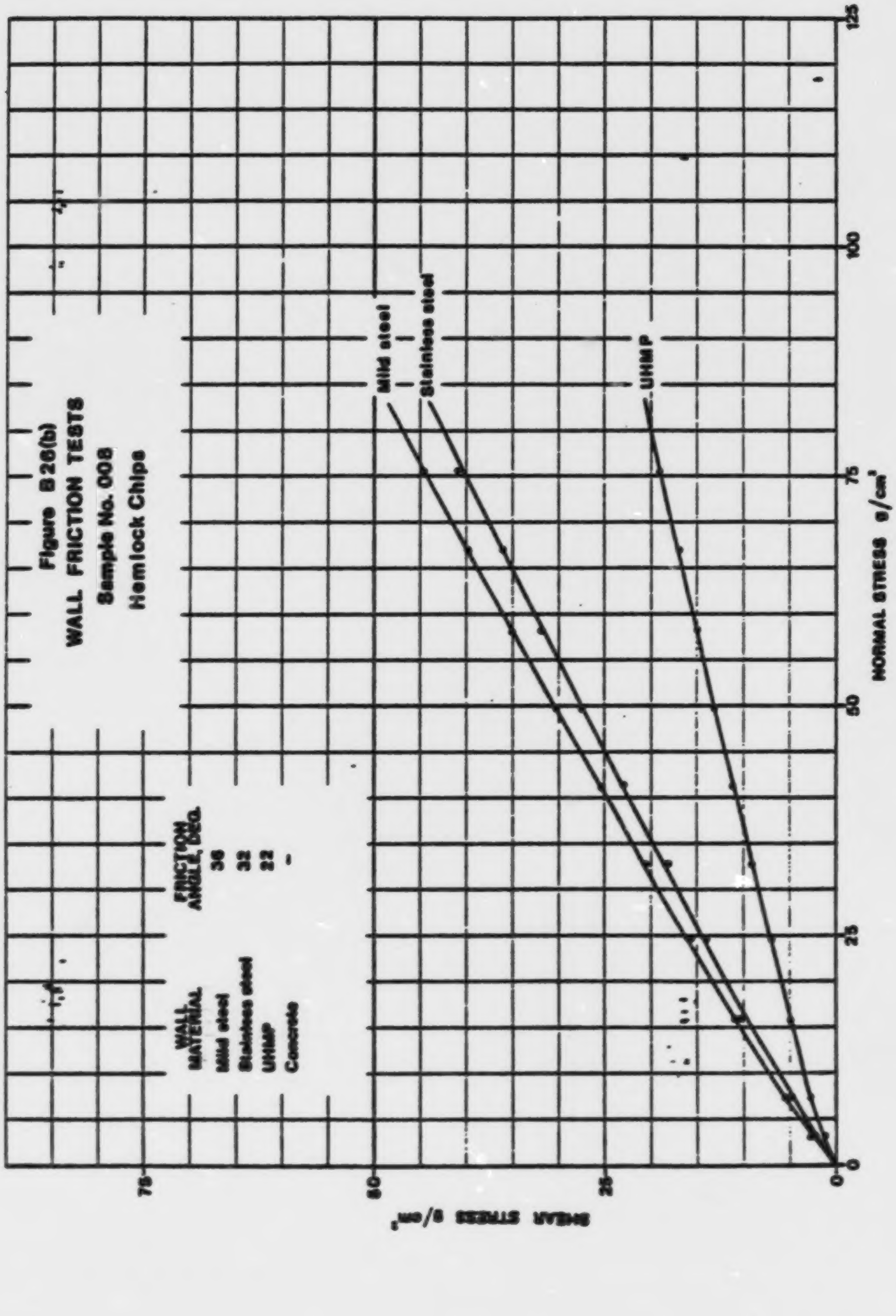
Figure B26(b)
WALL FRICTION TESTS
Sample No. 008
Hemlock Chips

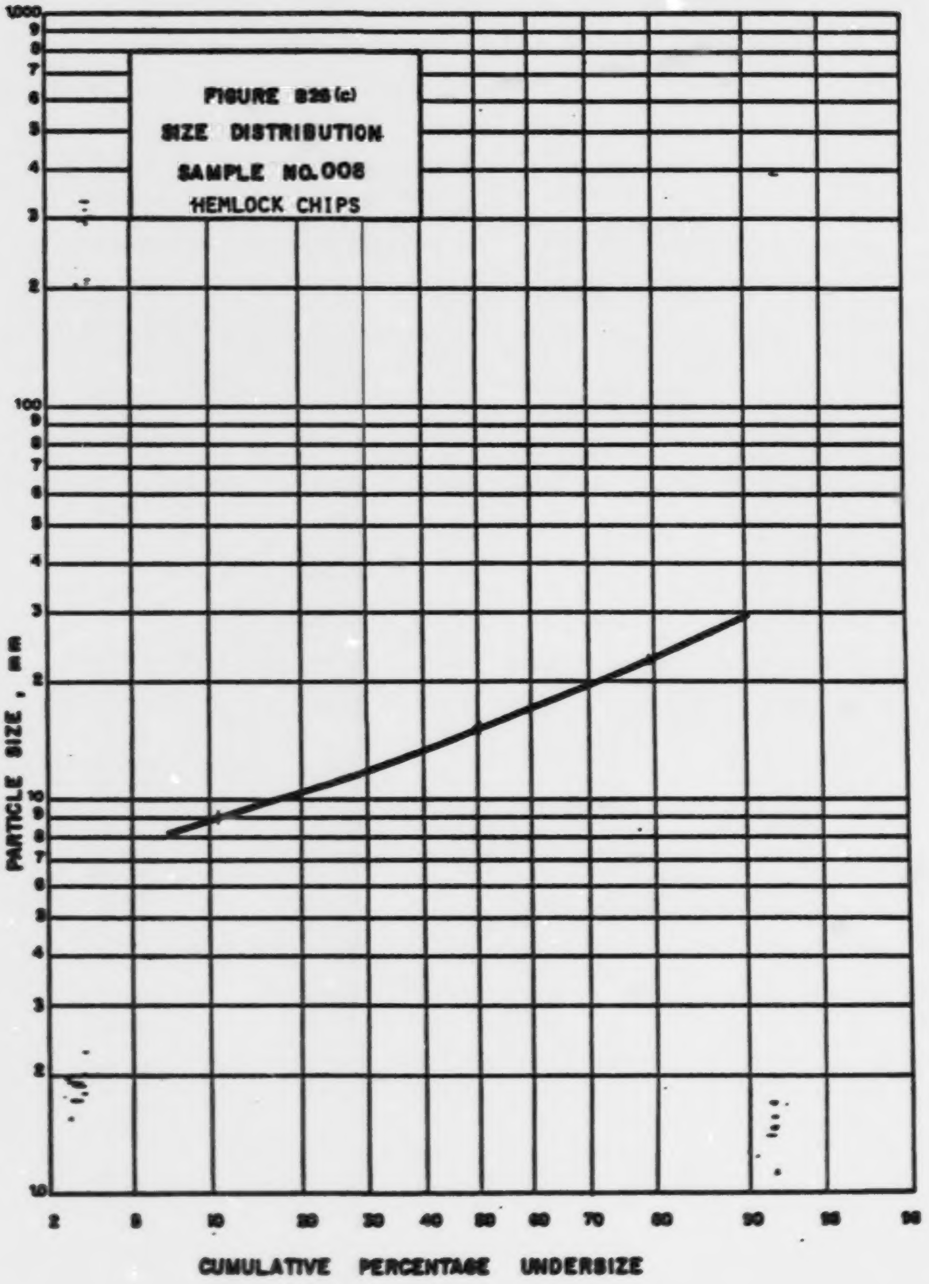

FIGURE B26(c)
SIZE DISTRIBUTION
SAMPLE NO.008
HEMLOCK CHIPS

TABLE B27 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

FIR CHIPS (MB-CAN. WHITE PINE DIV.) SAMPLE #013

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	40.8		
		2.5	4.8
		4.2	8.3
		8.4	13.6
		12.6	20.9
		16.8	26.2
		24.4	33.1
		27.0	40.8
48.1	73.0		
		4.2	22.5
		8.4	19.1
		16.8	34.2
		27.0	41.2
		33.7	51.4
		39.6	60.2
		48.1	73.0
59.9	83.0		
		4.2	7.2
		8.4	25.6
		16.8	46.8
		27.0	65.5
		43.8	72.4
		56.5	77.3
		59.9	83.0
81.8	121.7		
		4.2	18.0
		12.6	37.8
		27.0	52.0
		56.5	89.4
		59.9	107.1
		73.4	110.2
		81.8	121.7
98.7	125.7		
		4.2	15.5
		12.6	25.6
		27.0	53.7
		56.5	91.1
		73.4	115.4
		90.3	126.4
		98.7	125.7
115.6	154.4		
		4.2	13.5
		12.6	30.1
		27.0	68.4
		56.5	93.7
		81.8	117.9
		107.1	146.6
		115.6	154.4

TABLE B27 (b)

FIR CHIPS (MB-CAN. WHITE PINE DIV.) SAMPLE #013 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	40.8	84.0	28.8	2.92	58.7	62.51	3.01	.75
48.1	73.0	160.8	61.7	2.60	60.7	62.51	6.45	1.60
59.9	83.0	206.6	83.2	2.48	61.6	62.51	8.69	2.16
81.8	121.7	284.6	116.0	2.45	61.8	62.51	12.12	3.01
98.7	125.7	305.2	103.1	2.96	58.5	62.51	10.77	2.68
115.6	154.4	355.8	119.4	2.98	58.4	62.51	12.47	3.10

SHEAR INDEX (N) = 1.46

YIELD LOCUS	PERCENT FIT
1	98.3
2	98.9
3	97.7
4	99.5
5	99.5
6	99.6

TABLE B27 (c)

WALL FRICTION TEST RESULTS

FIR CHIPS (MB - WHITE PINE DIV.) SAMPLE 013

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	45.2
66.7	40.1
58.2	34.8
49.8	29.8
41.4	25.0
33.0	20.2
24.5	15.1
16.0	10.2
7.5	5.0
3.1	2.0

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	48.3
66.7	43.0
58.2	37.3
49.8	32.4
41.4	26.9
33.0	21.4
24.5	15.8
16.0	10.6
7.5	4.7
3.1	1.4

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (ALONG "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	16.7
66.7	14.9
58.2	13.1
49.8	11.5
41.4	9.7
33.0	7.7
24.5	5.9
16.0	4.0
7.5	2.0
3.1	.8

TABLE B27 (c) cont'd

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (ACROSS "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.2	17.7
66.7	15.7
58.2	13.8
49.8	11.8
41.4	9.9
33.0	8.0
24.5	6.1
16.0	4.0
7.5	2.0
3.1	.9

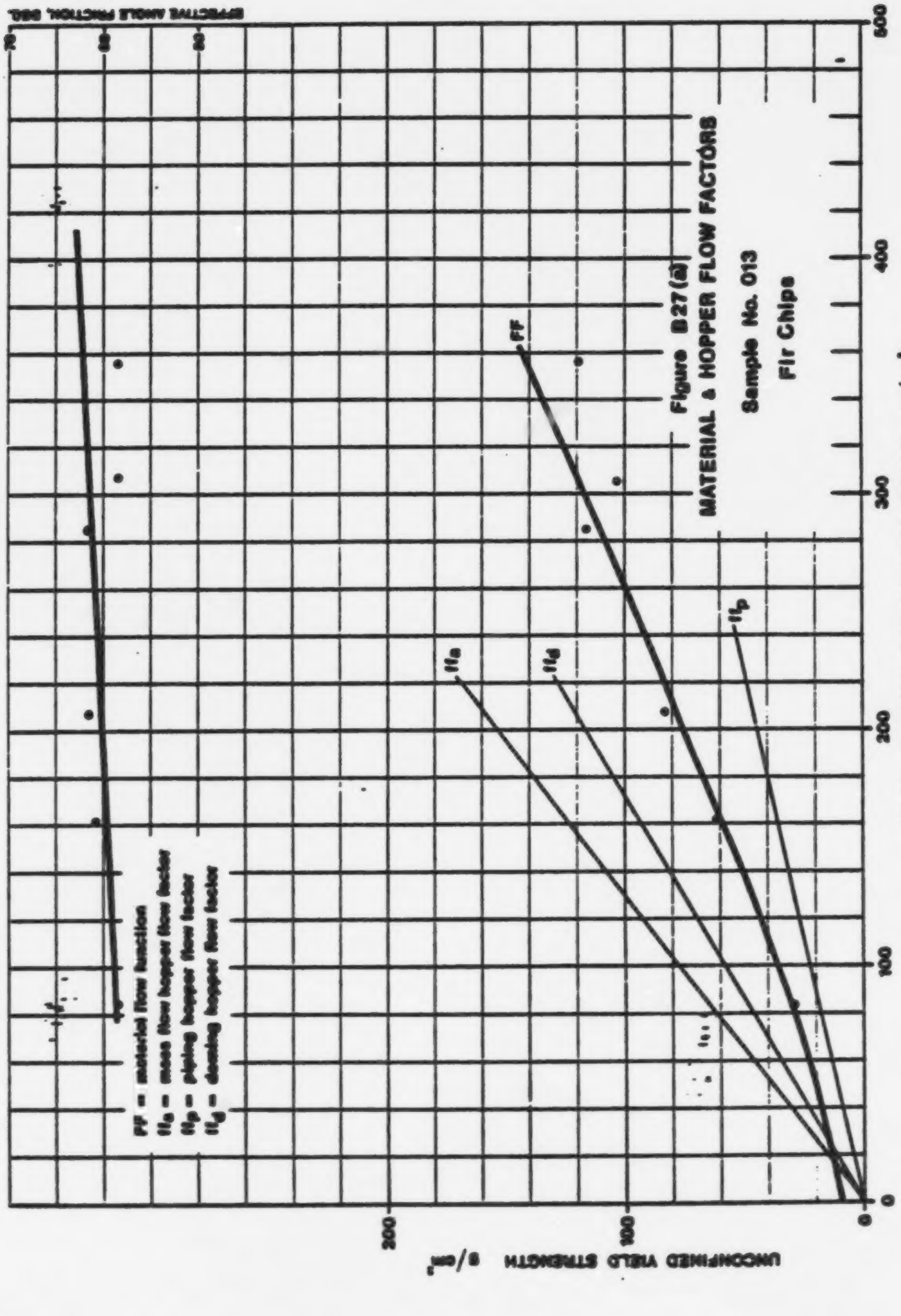

Figure B27(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 013
Fir Chips

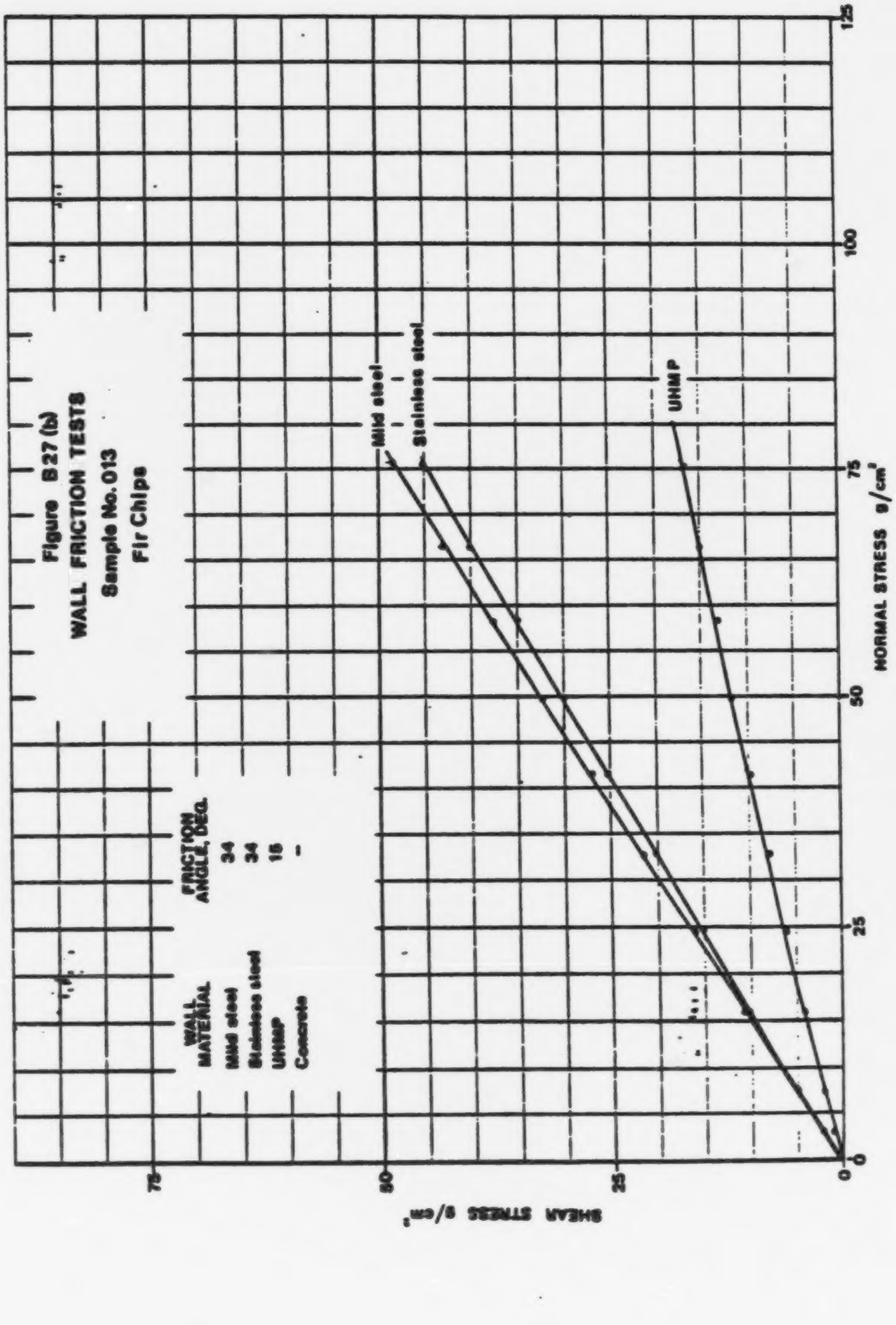

Figure B27 (b)
WALL FRICTION TESTS
Sample No. 013
Fir Chips

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	34
Stainless steel	34
UHMP	16
Concrete	–

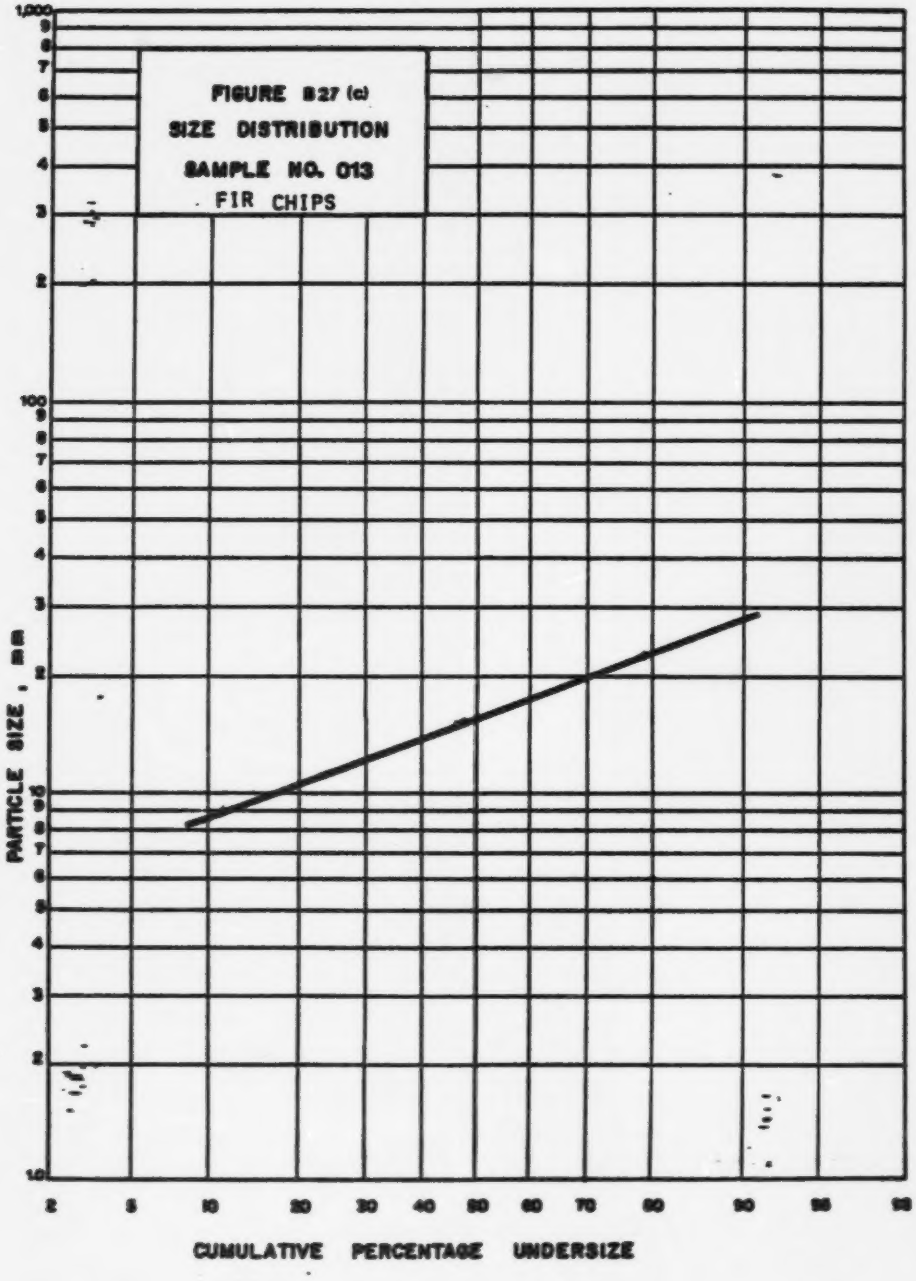
FIGURE B27 (c)
SIZE DISTRIBUTION
SAMPLE NO. 013
FIR CHIPS
PARTICLE SIZE, mm
CUMULATIVE PERCENTAGE UNDERSIZE
1,000
100
10
1.0
2
5
10
20
30
40
50
60
70
80
90
95
98

TABLE B28 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR CHIPS (HARMAC PULP MILL) SAMPLE # 015

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	36.0		
		2.5	8.9
		4.2	12.5
		8.4	17.8
		12.6	27.1
		16.8	27.8
		24.4	37.6
		27.0	36.0
48.1	68.0		
		4.2	17.1
		8.4	29.3
		16.8	51.2
		27.0	43.7
		33.7	59.9
		39.6	59.9
		48.1	68.0
59.9	85.6		
		4.2	21.1
		8.4	25.0
		16.8	39.7
		27.0	52.8
		43.8	76.1
		56.5	88.6
		59.9	85.6
81.8	112.0		
		4.2	26.6
		12.6	70.5
		27.0	54.7
		56.5	78.2
		59.9	85.1
		73.4	94.2
		81.8	112.0
98.7	131.0		
		4.2	15.8
		12.6	37.4
		27.0	54.3
		56.5	106.8
		73.4	120.4
		90.3	129.5
		98.7	131.0
115.6	151.3		
		4.2	26.8
		12.6	45.1
		27.0	71.6
		56.5	92.5
		81.8	116.7
		107.1	142.0
		115.6	151.3

TABLE B28 (b)

CEDAR CHIPS (HARMAC PULP MILL) SAMPLE # 015 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	36.0	79.5	53.9	1.47	64.8	53.72	6.76	1.52
48.1	68.0	149.7	107.6	1.39	67.0	53.72	13.49	3.03
59.9	85.6	184.9	131.7	1.40	66.7	53.72	16.52	3.71
81.8	112.0	230.3	148.4	1.55	63.0	53.72	18.61	4.18
98.7	131.0	284.6	188.5	1.51	64.0	53.72	23.63	5.31
115.6	151.3	314.2	194.1	1.62	61.6	53.72	24.34	5.47

SHEAR INDEX (N) = 1.74

YIELD LOCUS	PERCENT FIT
1	99.0
2	98.3
3	99.2
4	96.7
5	98.5
6	99.7

TABLE B28 (c)

WALL FRICTION TEST RESULTS

CEDAR CHIPS (MB - HARMAC) SAMPLE 015

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.4	43.0
66.9	38.4
58.4	33.4
49.9	28.9
41.5	24.2
33.1	19.7
24.6	15.1
16.1	10.4
7.6	5.4
3.3	2.4

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.4	47.5
66.9	42.7
58.4	36.9
49.9	32.3
41.5	27.0
33.1	21.9
24.6	16.6
16.1	11.2
7.6	5.7
3.3	2.4

WALL MATERIAL - ULTRA HIGH MOL. PLOYMER (ALONG "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.4	17.9
66.9	16.0
58.4	14.2
49.9	12.4
41.5	10.6
33.1	8.7
24.6	6.8
16.1	4.8
7.6	2.5
3.3	1.1

TABLE B28 (c) con't

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (ACROSS "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.4	19.9
66.9	17.9
58.4	15.7
49.9	13.6
41.5	11.6
33.1	9.6
24.6	7.3
16.1	5.2
7.6	2.7
3.3	1.3

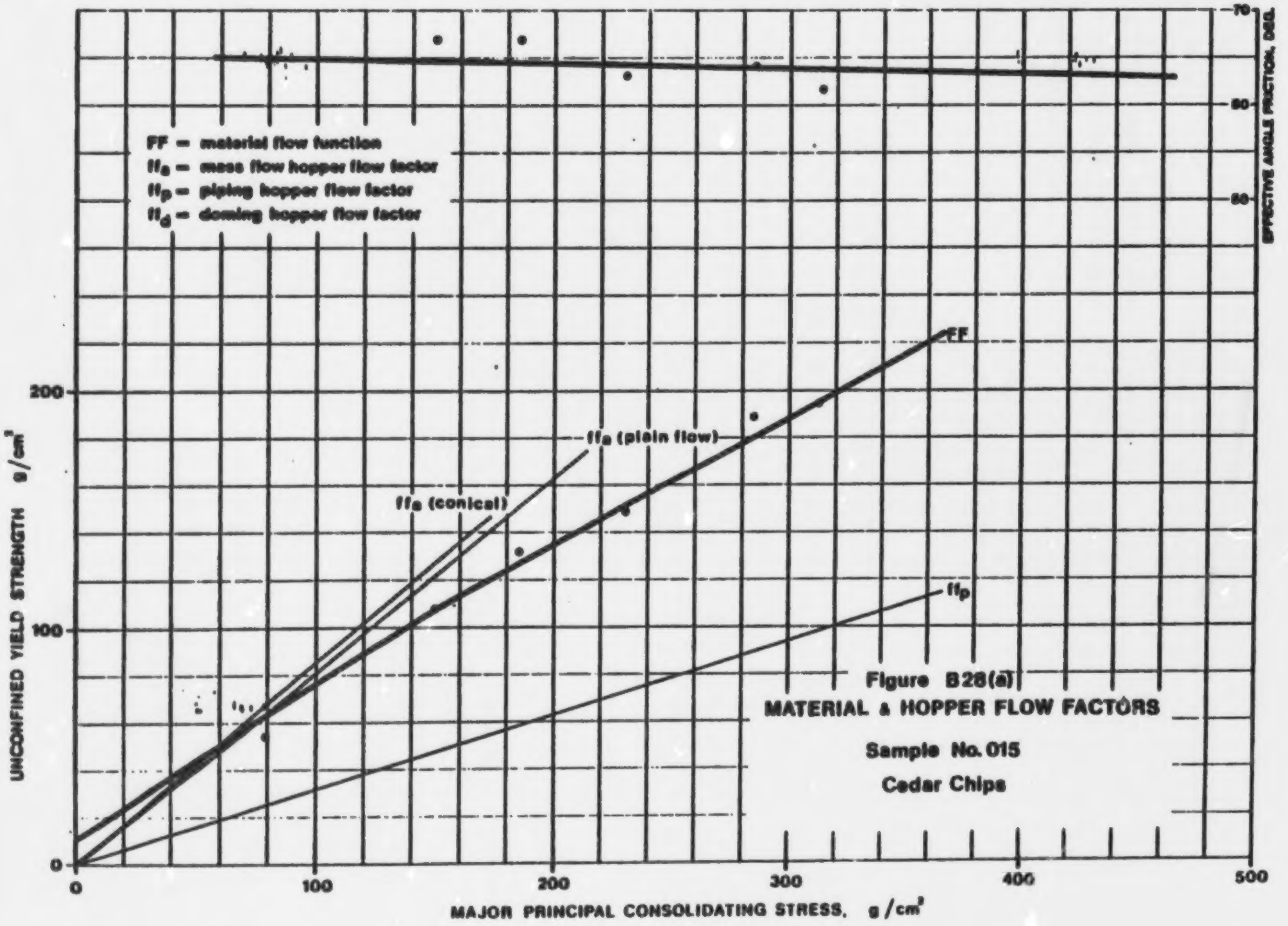

Figure B28(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 015
Cedar Chips

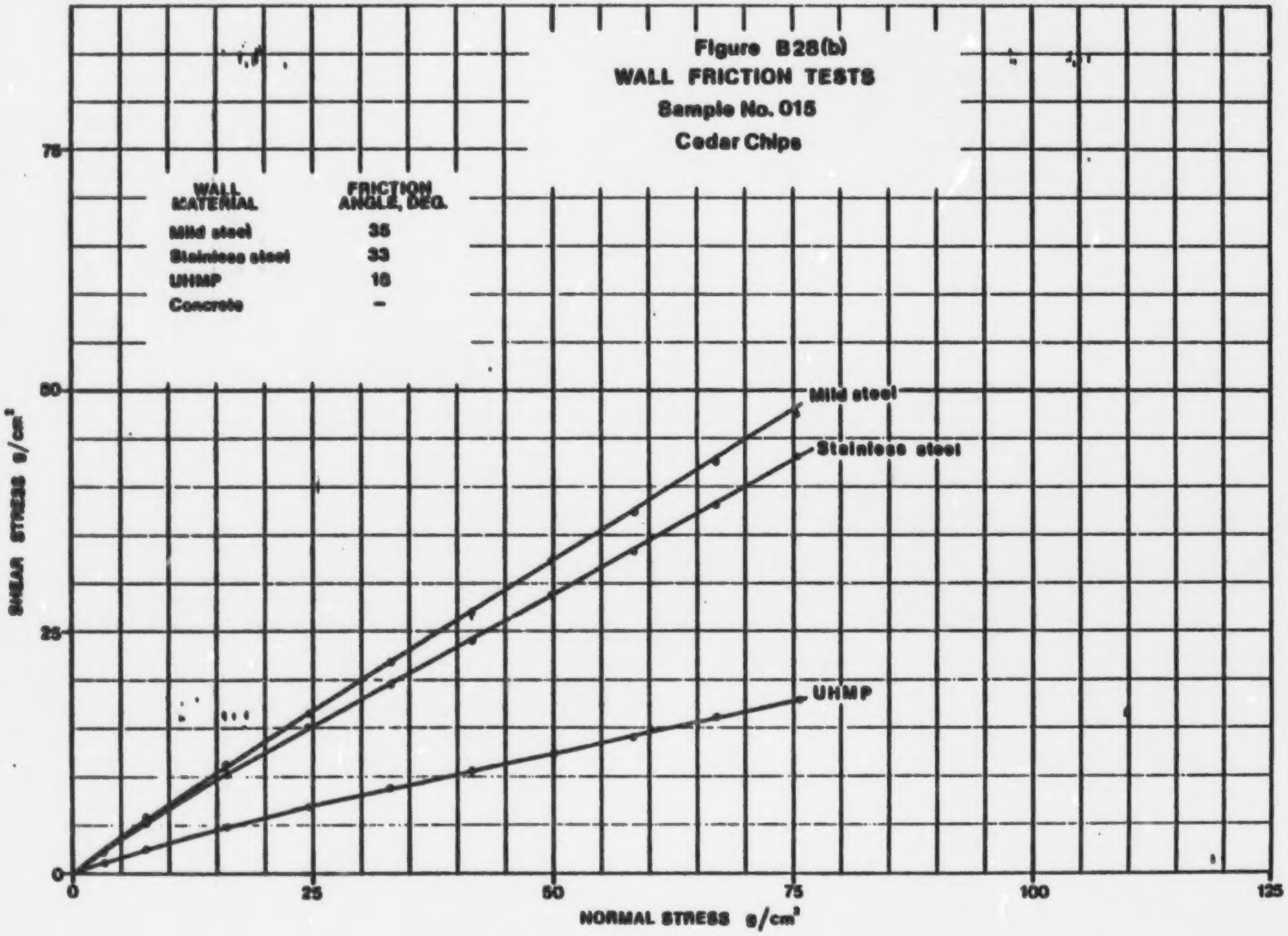

Figure B28(b)
WALL FRICTION TESTS
Sample No. 015
Cedar Chips

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	35
Stainless steel	33
UHMP	16
Concrete	–

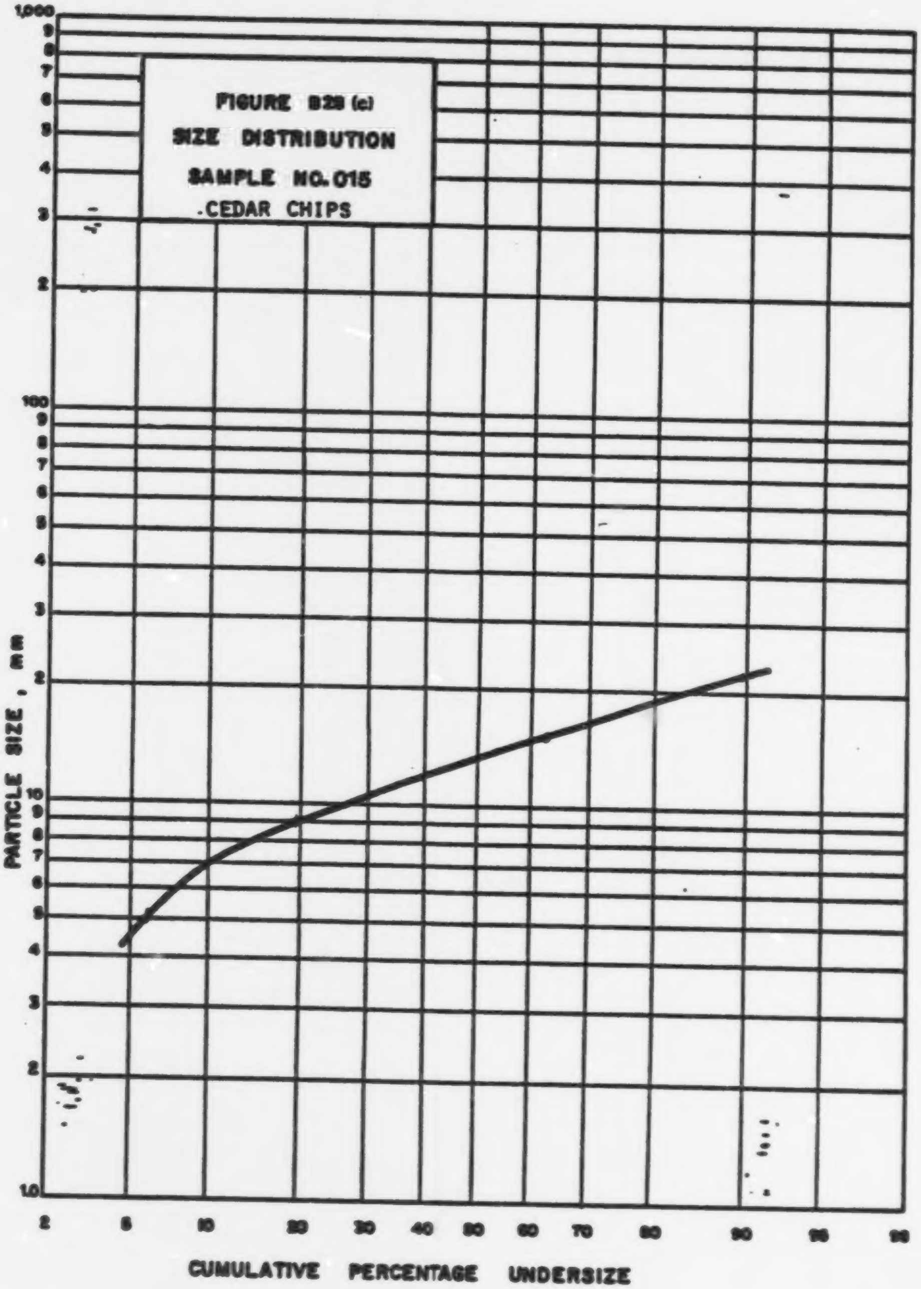

FIGURE B29 (c)
SIZE DISTRIBUTION
SAMPLE NO. 015
.CEDAR CHIPS

TABLE B29 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK CHIPS (NORTHWOOD PULP) SAMPLE # 020

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM
27.0	32.2		
		2.5	16.5
		4.2	9.7
		8.4	14.7
		12.6	30.1
		16.8	24.0
		24.4	30.3
		27.0	32.2
48.1	81.7		
		4.2	15.4
		8.4	30.0
		16.8	32.9
		27.0	49.9
		33.7	66.4
		39.5	74.9
		48.1	81.7
59.9	98.6		
		4.2	15.4
		8.4	37.4
		16.8	50.9
		27.0	80.2
		43.8	83.6
		56.5	89.2
		59.9	98.6
81.8	110.4		
		4.2	30.2
		12.6	32.7
		27.0	54.9
		56.5	80.9
		59.9	99.2
		73.4	104.6
		81.8	110.4
98.7	137.3		
		4.2	25.2
		12.6	39.9
		27.0	70.5
		56.5	115.7
		73.4	128.5
		90.3	176.9
		98.7	137.3
115.6	152.9		
		4.2	22.6
		12.6	35.7
		27.0	89.2
		56.5	114.8
		81.8	137.9
		107.1	160.4
		115.6	152.9

TABLE B29 (b)

HEMLOCK CHIPS (NORTHWOOD PULP) SAMPLE # 020 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	32.2	75.6	38.9	1.94	60.2	58.70	4.24	.88
48.1	81.7	174.4	119.8	1.46	68.7	58.70	13.03	2.70
59.9	98.6	227.7	163.4	1.39	70.1	58.70	17.78	3.68
81.8	110.4	243.3	134.9	1.80	62.2	58.70	14.68	3.04
98.7	137.3	349.2	234.1	1.49	67.9	58.70	25.48	5.28
115.6	152.9	364.2	216.1	1.68	64.2	58.70	23.52	4.87

SHEAR INDEX (N) = 1.66

YIELD LOCUS	PERCENT FIT
1	95.2
2	98.3
3	98.2
4	99.4
5	97.7
6	98.8

TABLE B29 (c)

WALL FRICTION TEST RESULTS

HEMLOCK CHIPS (NORTHWOOD PULP) SAMPLE 020

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.7	44.8
67.1	40.1
58.7	34.6
50.2	30.2
41.8	25.2
33.4	20.3
24.9	15.2
16.4	10.4
7.9	5.2
3.6	2.2

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.7	46.9
67.1	41.9
58.7	36.8
50.2	31.5
41.8	26.2
33.4	21.1
24.9	16.0
16.4	10.6
7.9	5.2
3.6	2.3

WALL MATERIAL - ULTRA HIGH MOL. POYMER (ALONG "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.7	17.7
67.1	15.8
58.7	13.8
50.2	12.0
41.8	10.1
33.4	8.3
24.9	6.4
16.4	4.4
7.9	22.9
3.6	1.1

TABLE B29 (c) con't.

WALL MATERIAL - ULTRA HIGH MOL. POLYMER (ACROSS "GRAIN")

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
75.7	19.0
67.1	16.7
58.7	14.7
50.2	12.5
41.8	10.6
33.4	8.7
24.9	7.1
16.4	4.6
7.9	2.5
3.6	1.1

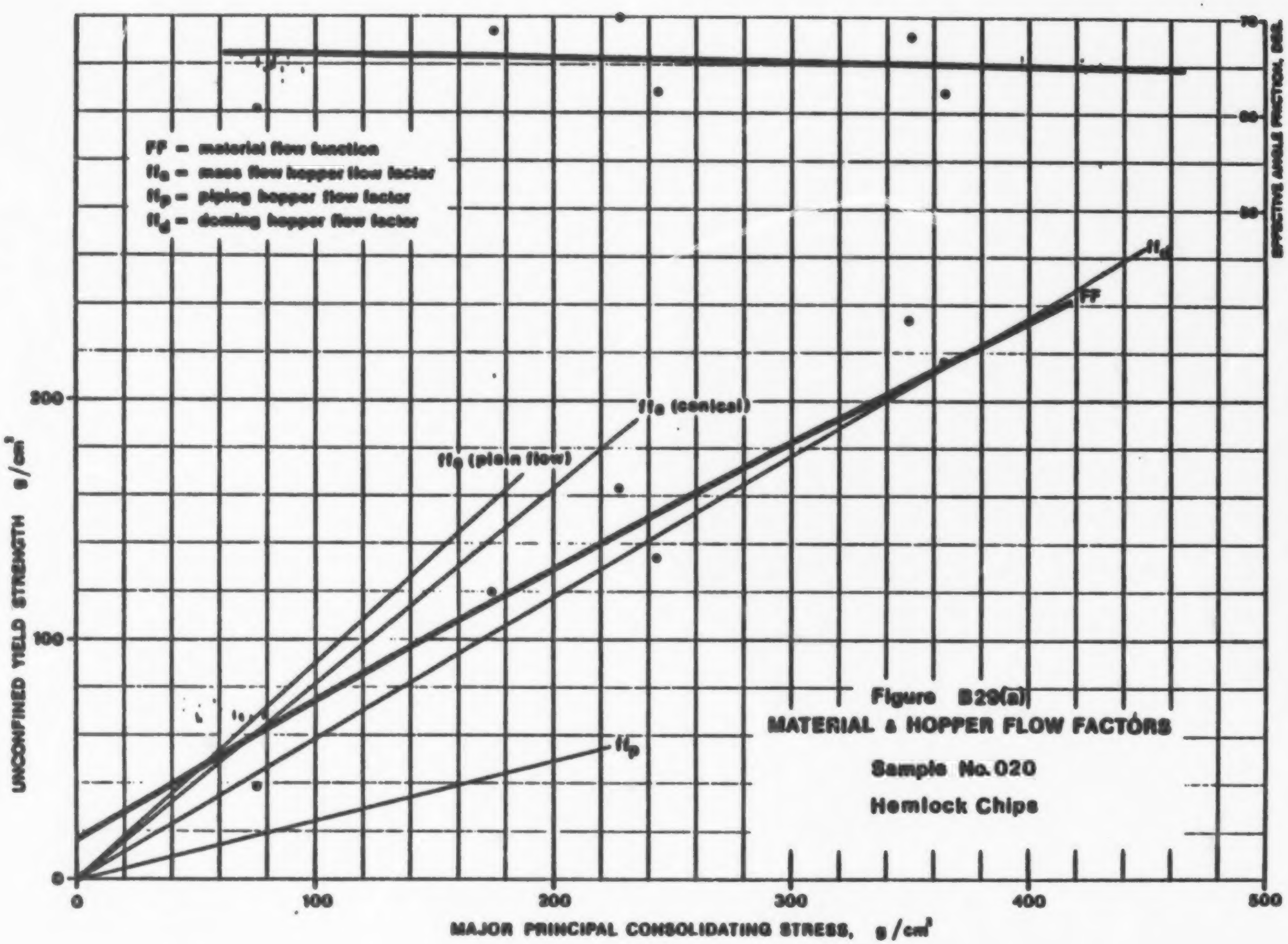

Figure B29(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 020
Hemlock Chips

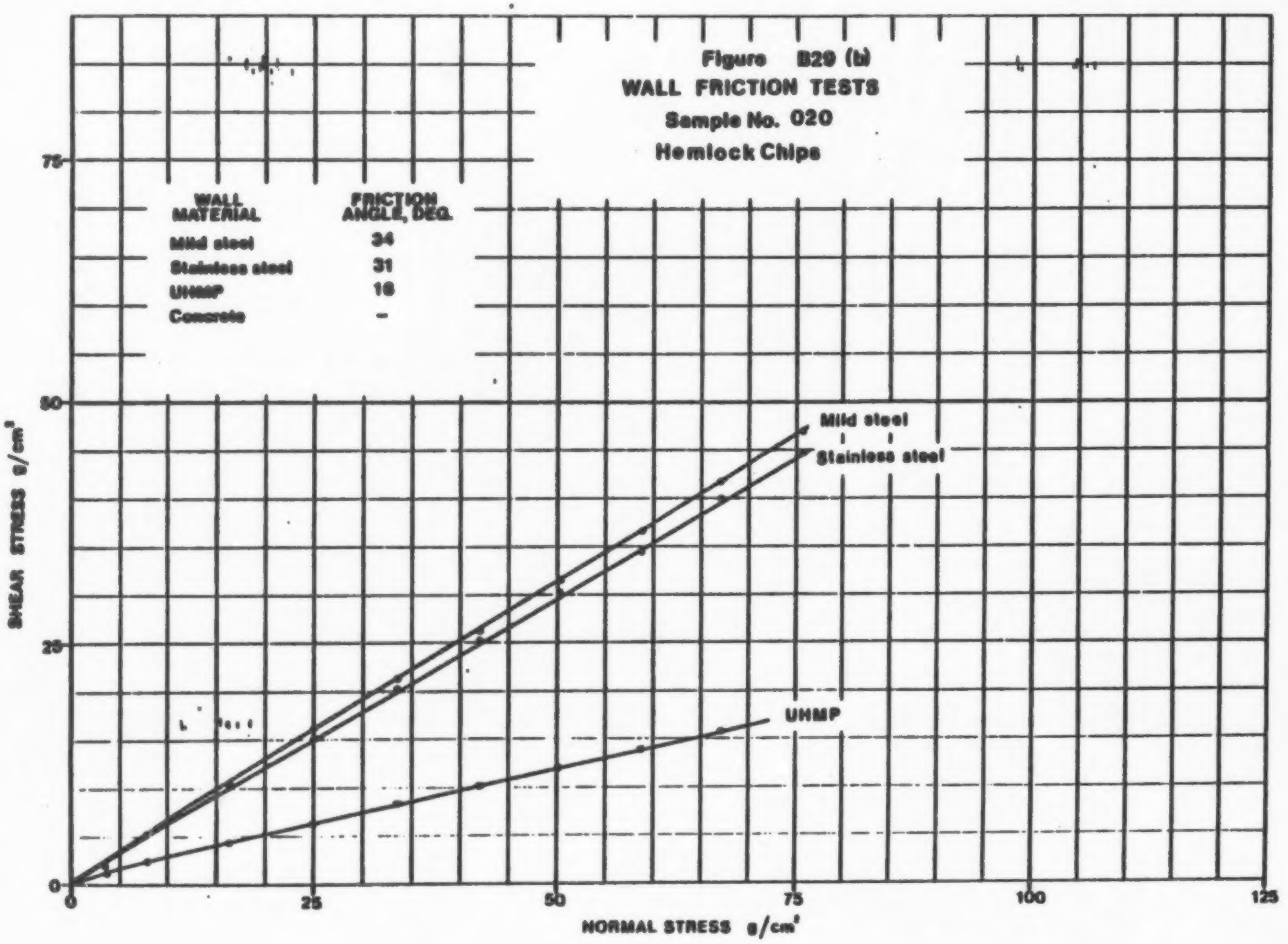

Figure B29 (b)
WALL FRICTION TESTS
Sample No. 020
Hemlock Chips

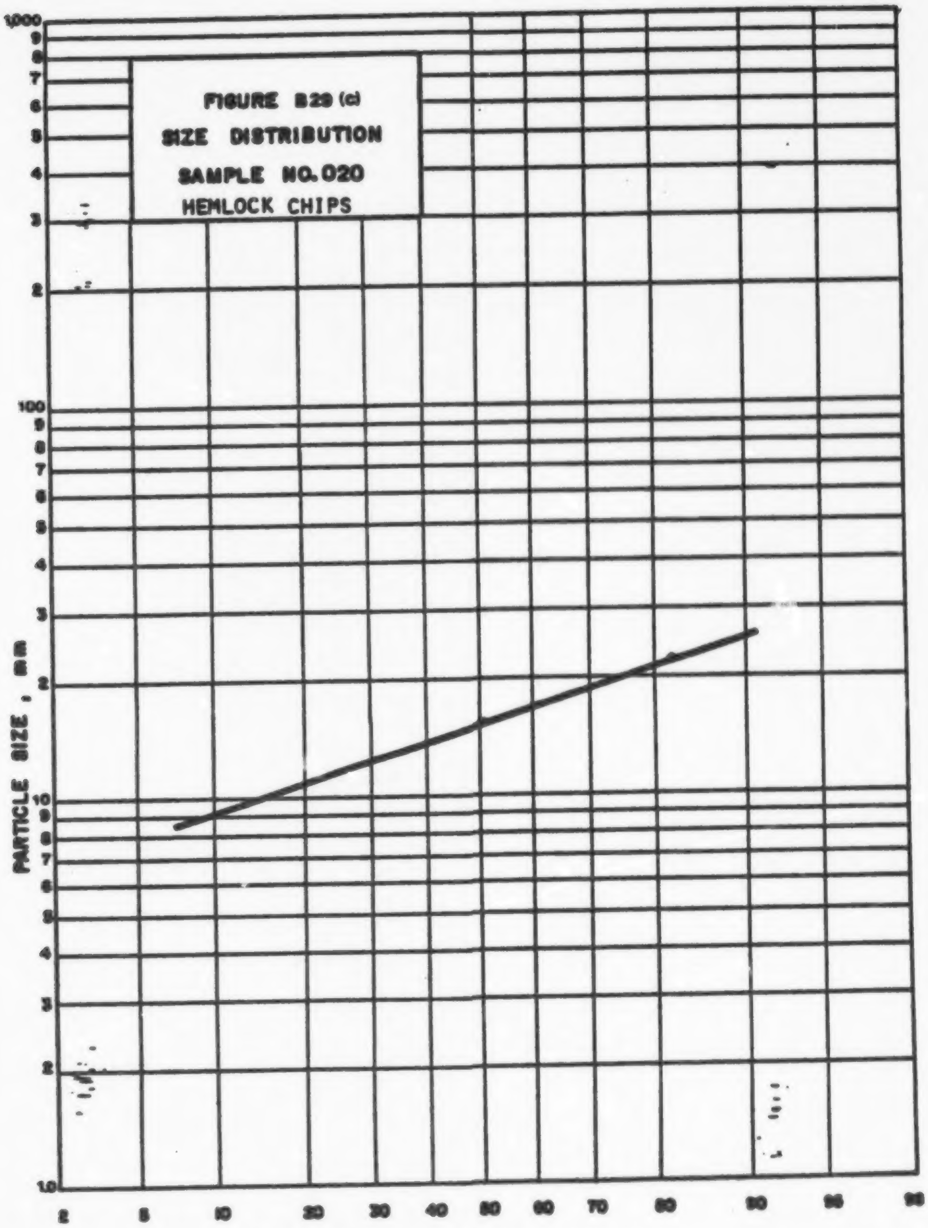
FIGURE B29 (c)
SIZE DISTRIBUTION
SAMPLE NO. 020
HEMLOCK CHIPS
PARTICLE SIZE, mm
CUMULATIVE PERCENTAGE UNDERSIZE
1,000
100
10
1.0
2
5
10
20
30
40
50
60
70
80
90
95
98

TABLE B30 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK CHIPS (WONNOCK LUMBER) SAMPLE 025

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	45.3		
		2.5	10.3
		4.2	18.6
		8.4	18.6
		12.6	24.8
		16.8	28.2
		24.4	31.6
		27.0	45.3
48.1	71.0		
		4.2	6.6
		8.4	20.2
		16.8	36.5
		27.0	35.8
		33.7	45.9
		39.6	63.9
		48.1	71.0
59.9	88.7		
		4.2	17.9
		8.4	41.6
		16.8	45.6
		27.0	67.3
		43.8	78.0
		56.5	86.1
		59.9	88.7
81.8	109.2		
		4.2	14.6
		12.6	47.7
		27.0	68.0
		56.5	86.1
		59.9	88.9
		73.4	93.6
		81.8	109.2
98.7	139.2		
		4.2	11.2
		12.6	25.0
		27.0	71.1
		56.5	111.1
		73.4	118.6
		90.3	135.7
		98.7	139.2
115.6	143.5		
		4.2	28.4
		12.6	46.1
		27.0	104.8
		56.5	116.1
		81.8	122.3
		107.1	133.8
		115.6	143.5

TABLE B30 (b)

HEMLOCK CHIPS (WONNOCK LUMBER) SAMPLE 025 (CONT.)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	45.3	82.3	60.3	1.37	67.1	53.03	7.60	1.67
48.1	71.0	131.4	85.3	1.54	62.6	53.03	10.77	2.36
59.9	88.7	196.3	153.7	1.28	70.0	53.03	19.39	4.25
81.8	109.2	227.4	150.5	1.51	63.3	53.03	18.99	4.16
98.7	139.2	291.3	205.9	1.41	65.7	53.03	25.98	5.69
115.6	143.5	325.5	218.6	1.49	63.8	53.03	27.57	6.04

SHEAR INDEX (N) = 1.77

YIELD LOCUS	PERCENT FIT
1	97.5
2	95.7
3	99.0
4	98.9
5	97.3
6	97.4

TABLE B30 (c)

WALL FRICTION TEST RESULTS

HEMLOCK CHIPS (WONNOCK LUMBER) SAMLPE 025)

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.0	36.9
67.5	33.0
59.0	29.0
50.5	24.9
42.1	20.5
33.7	16.7
25.2	12.7
16.7	8.6
8.2	4.5
3.9	2.2

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.0	41.2
67.5	36.8
59.0	32.3
50.5	27.8
42.1	23.3
33.7	18.7
25.2	14.2
16.7	9.7
8.2	5.0
3.9	2.2

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.0	18.1
67.5	16.2
59.0	14.2
50.5	12.4
42.1	10.6
33.7	8.6
25.2	6.6
16.7	4.7
8.2	2.5
3.9	1.2

TABLE B30 (c) con't

WALL FRICTION TEST RESULTS

HEMLOCK CHIPS (WONNOCK LUMBER) SAMPLE 025 (CONT.)

WALL MATERIAL - PLASTIC COATING (DELTA PLASTICS)

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
76.0	38.0
67.5	34.1
59.0	30.6
50.5	26.5
42.1	21.9
33.7	17.9
25.2	13.6
16.7	9.2
8.2	4.8
3.9	2.3

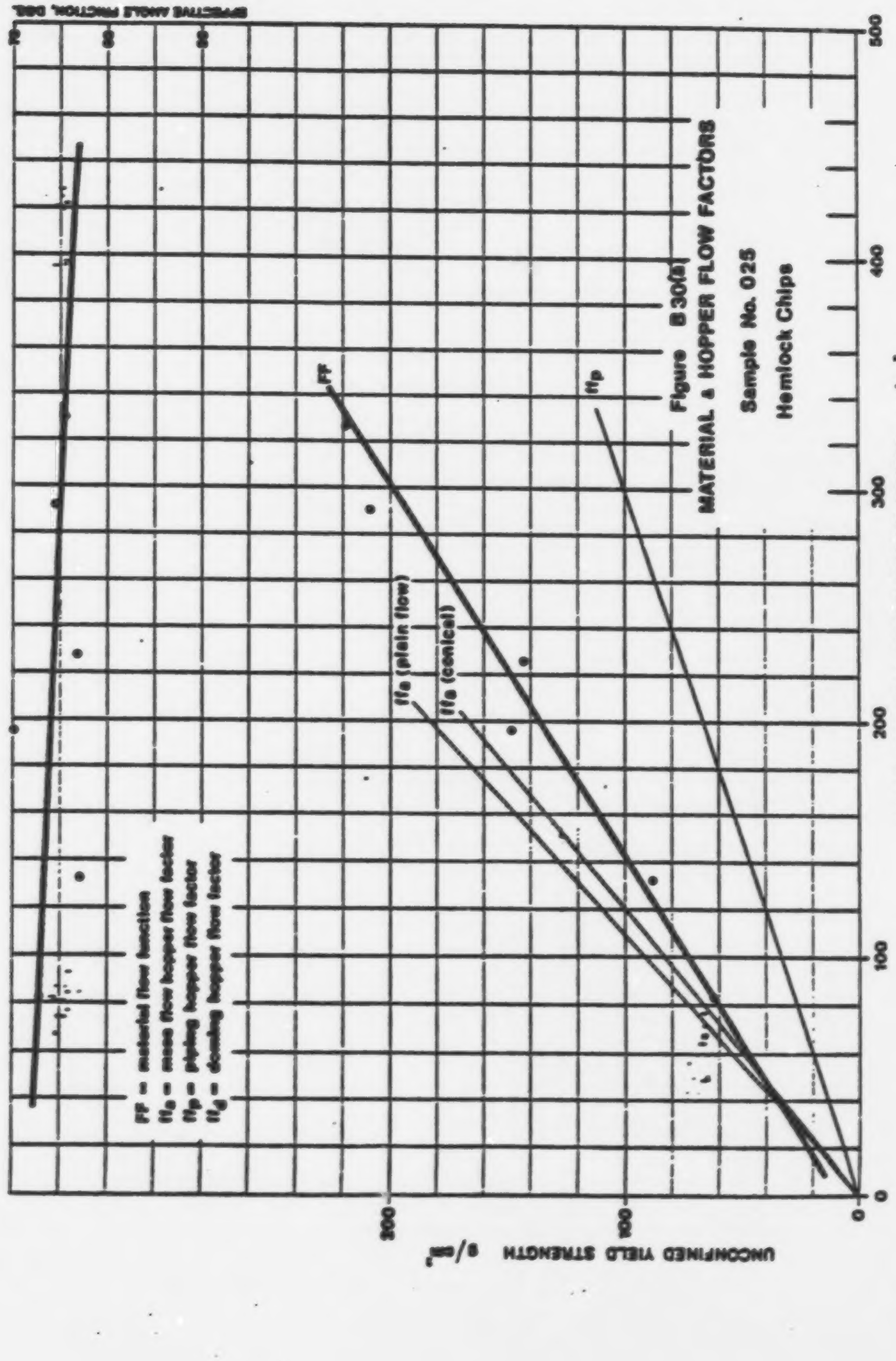
Figure B30(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 025
Hemlock Chips

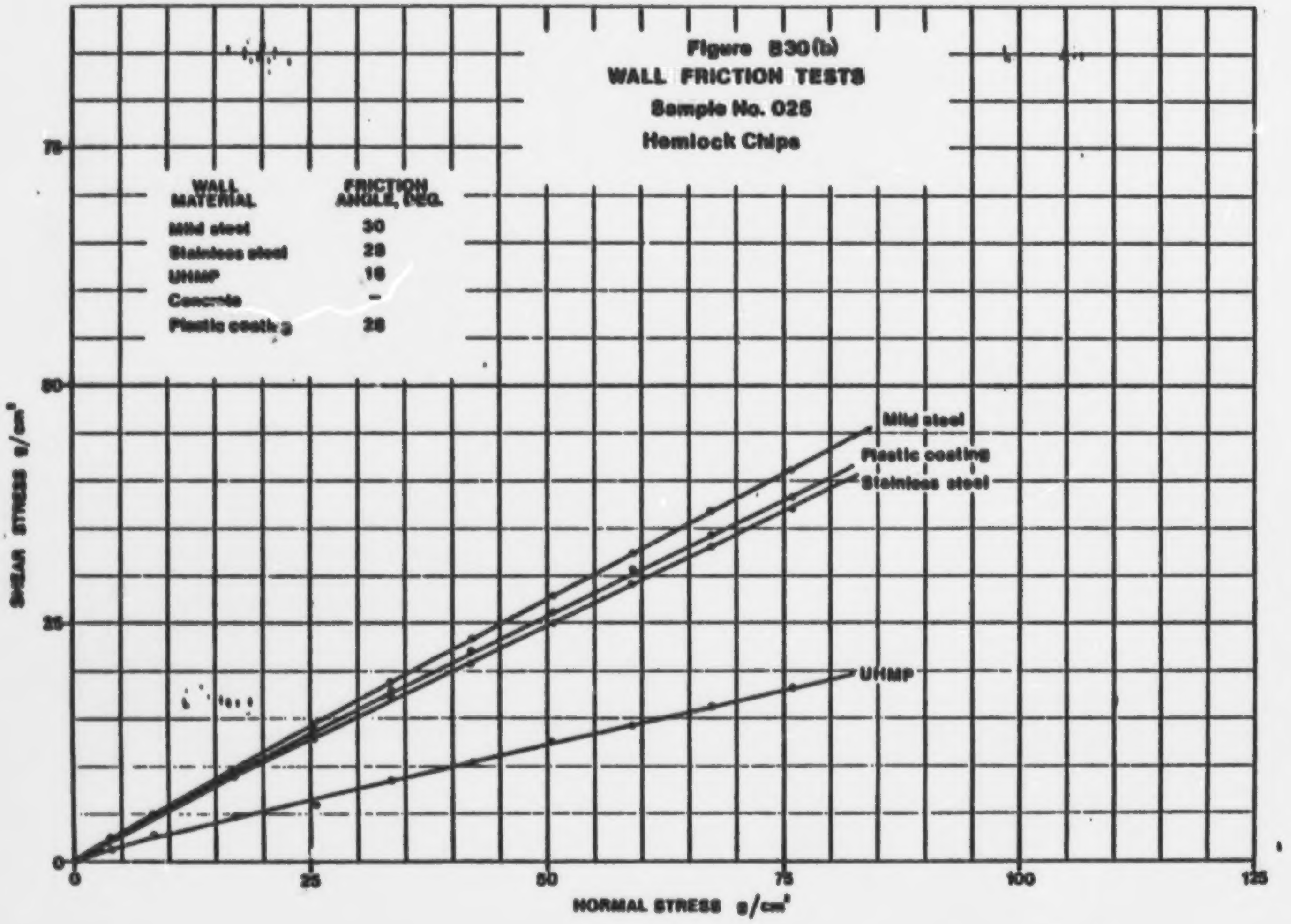

Figure B30(b)
WALL FRICTION TESTS
Sample No. 025
Hemlock Chips

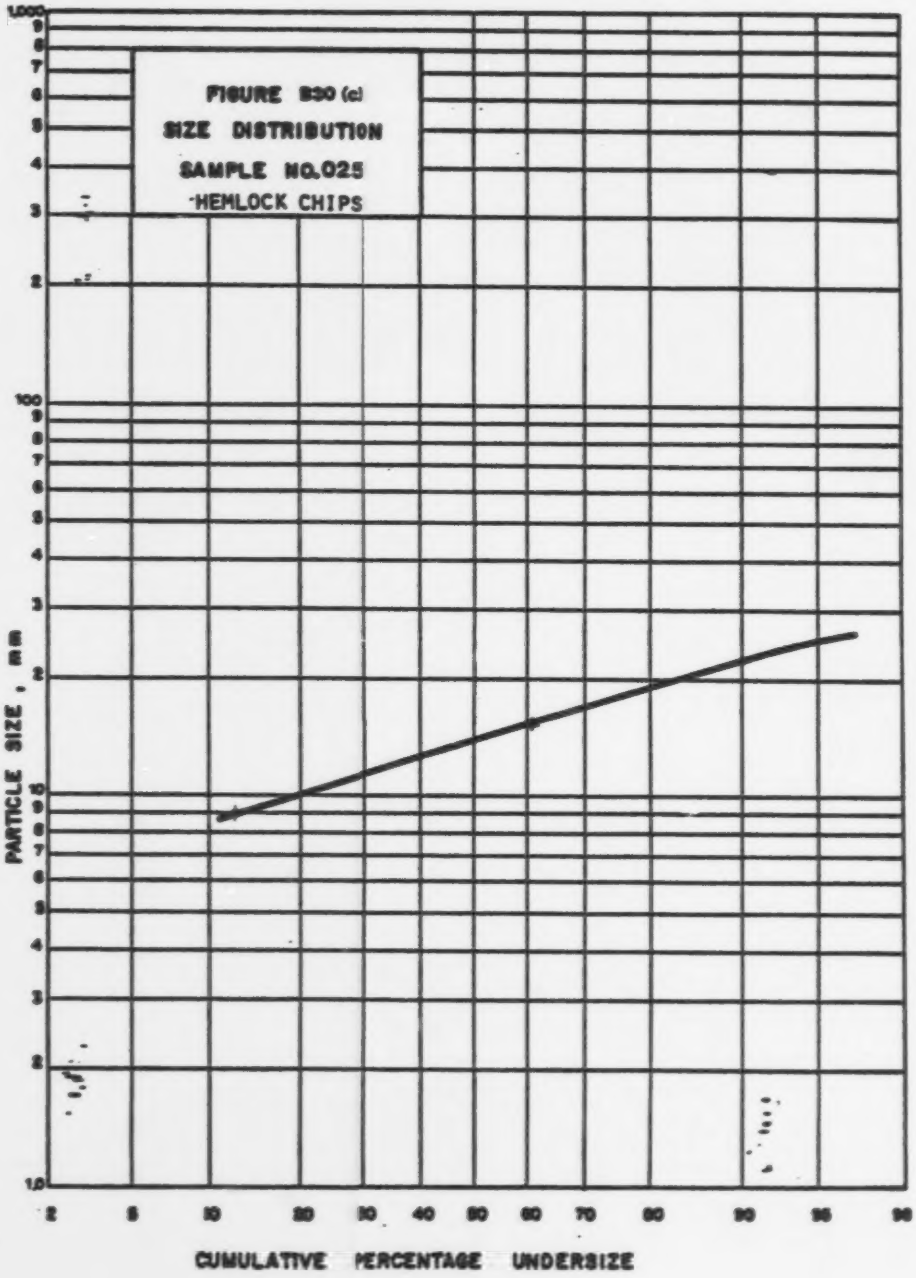

FIGURE B30 (c)
SIZE DISTRIBUTION
SAMPLE NO.025
HEMLOCK CHIPS

TABLE B31 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK CHIPS (WONNOCK LUMBER) SAMPLE 025-C
- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	35.0		
		2.5	7.7
		4.2	10.3
		8.4	14.4
		12.6	15.9
		16.8	23.4
		24.4	34.4
		27.0	35.0
48.1	65.6		
		4.2	12.5
		8.4	13.0
		16.8	39.1
		27.0	47.0
		33.7	60.8
		39.5	65.0
		48.1	65.6
59.9	78.9		
		4.2	9.4
		8.4	16.5
		16.8	39.1
		27.0	50.2
		43.8	71.1
		56.5	83.9
		59.9	78.9
81.8	106.1		
		4.2	10.6
		12.6	43.8
		27.0	51.2
		56.5	88.7
		59.9	94.6
		73.4	100.3
		81.8	106.1
98.7	150.4		
		4.2	36.9
		12.6	74.0
		27.0	84.2
		56.5	91.1
		73.4	119.2
		90.3	127.9
		98.7	150.4
115.6	179.4		
		4.2	42.7
		12.6	45.7
		27.0	78.6
		56.5	99.3
		81.8	132.6
		107.1	145.1
		115.6	179.4

TABLE B31 (b)

HEMLOCK CHIPS (WONNOCK LUMBER) SAMPLE 025-C)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	35.0	71.2	35.5	2.00	58.1	56.68	4.19	.96
48.1	65.6	148.1	90.5	1.64	63.9	56.68	10.68	2.45
59.9	78.9	176.0	101.5	1.73	62.2	56.68	11.98	2.74
81.8	106.1	235.7	132.6	1.78	61.5	56.68	15.65	3.58
98.7	150.4	324.6	213.1	1.52	66.1	56.68	25.15	5.76
115.6	179.4	362.5	225.8	1.61	64.5	56.68	26.65	6.10

SHEAR INDEX (N) = 1.65

YIELD LOCUS	PERCENT FIT
1	97.9
2	97.5
3	98.1
4	99.1
5	98.1
6	99.1

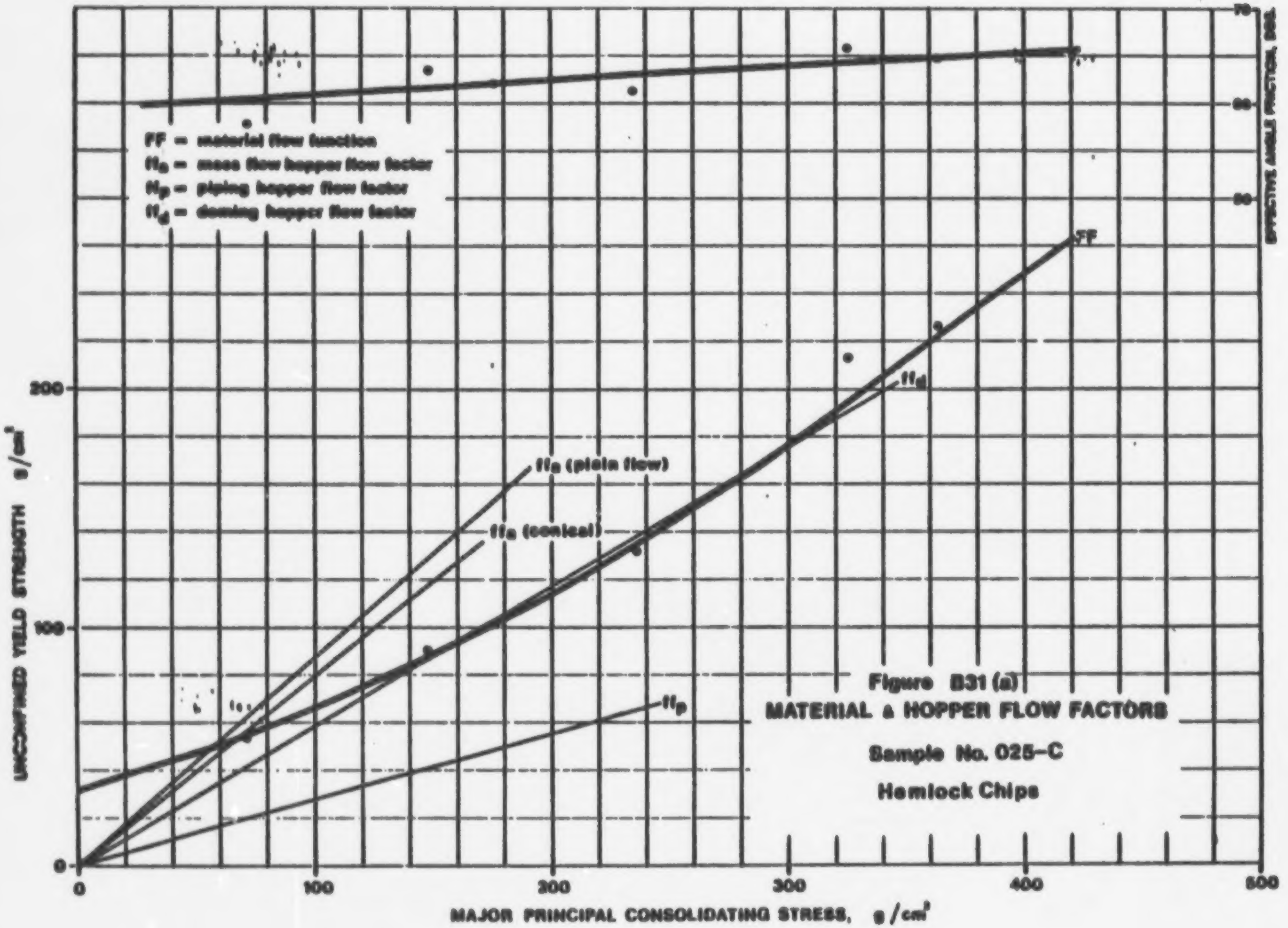

Figure B31 (a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 025-C
Hemlock Chips

TABLE B32 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK SHAVINGS - CANFOR (EBURNE) SAMPLE 0009

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
27.0	34.0		
		2.5	8.7
		4.2	12.7
		8.4	22.7
		12.6	25.5
		16.8	29.6
		24.4	32.4
		27.0	34.0
48.1	80.6		
		4.2	14.9
		8.4	20.3
		16.8	34.4
		27.0	44.9
		33.7	54.0
		39.6	58.3
		48.1	80.6
59.9	86.4		
		4.2	16.0
		8.4	24.0
		16.8	39.3
		27.0	70.8
		43.8	73.1
		56.5	84.4
		59.9	86.4
81.8	118.6		
		4.2	13.7
		12.6	39.9
		27.0	60.5
		56.5	91.7
		59.9	93.0
		73.4	104.8
		81.8	118.6
98.7	131.0		
		4.2	19.2
		12.6	45.1
		27.0	66.9
		56.5	86.7
		73.4	93.9
		90.3	117.0
		98.7	131.0
115.6	146.6		
		4.2	15.6
		12.6	35.6
		27.0	72.3
		56.5	109.8
		81.8	116.4
		107.1	144.8
		115.6	146.6

TABLE B32 (b)

HEMLOCK SHAVINGS - CANFOR (EBURNE) SAMPLE 0009 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGT
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	34.0	83.4	42.1	1.98	61.6	59.35	4.70	1.10
48.1	80.6	156.6	84.6	1.85	63.3	59.35	9.43	2.21
59.9	86.4	202.8	114.8	1.77	64.5	59.35	12.81	3.00
81.8	118.6	258.5	134.2	1.93	62.3	59.35	14.96	3.51
98.7	131.0	282.0	127.4	2.21	59.0	59.35	14.21	3.33
115.6	146.6	338.7	158.7	2.13	59.8	59.35	17.70	4.15

SHEAR INDEX (N) = 1.57

YIELD LOCUS	PERCENT FIT
1	98.8
2	98.3
3	98.4
4	99.6
5	99.3
6	99.2

TABLE B32 (c)

WALL FRICTION TEST RESULTS

HEMLOCK SHAVINGS (CANFOR - EBURNE) SAMPLE 009

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
74.5	43.7
66.0	39.1
57.5	34.4
49.1	29.6
40.7	24.9
32.3	20.3
23.8	15.5
15.3	10.8
6.8	5.4
2.4	1.8

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
74.5	48.7
66.0	44.1
57.5	39.1
49.1	33.7
40.7	28.5
32.3	23.0
23.8	17.6
15.3	12.1
6.8	5.8
2.4	1.8

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
74.5	20.0
66.0	17.9
57.5	15.8
49.1	13.9
40.7	11.6
32.3	9.5
23.8	7.3
15.3	5.0
6.8	2.5
2.4	.8

TABLE B32 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

HEMLOCK SHAVINGS SAMPLE #009

                          - TIME CONSOLIDATION RESULTS

CONSOLIDATION   YIELD POINT     <----------------FLOW PROPERTIES---------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC     UNCONFIN  EFFECT  INTERNAL  COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N      YIELD     FRIC    FRIC ANG
                                  STRESS      STRESS    ANGLE   AT FREE
                               INST   TIME                        SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM      G/SQ CM    DEG       DEG    G/SQ CM


CONSOLIDATION PERIOD  2 HOURS

  48.1    76.1    56.5    75.5  156.6  156.0   82.9      63.0      59.5     9.21
  81.8    97.7    81.8   126.4  258.5  292.1  173.9      65.9      59.5    19.31

CONSOLIDATION PERIOD  20 HOURS

  48.1    67.0    48.1    71.8  156.6  180.3   93.8      62.5      59.5    10.41

CONSOLIDATION PERIOD  66 HOURS

  48.1    69.3    48.1    76.1  156.6  176.8  108.8      66.8      59.5    12.09


                    SHEAR INDEX (N)    =   1.57

                    COHESION/ TENSILE
                             STRENGTH =   4.27
```

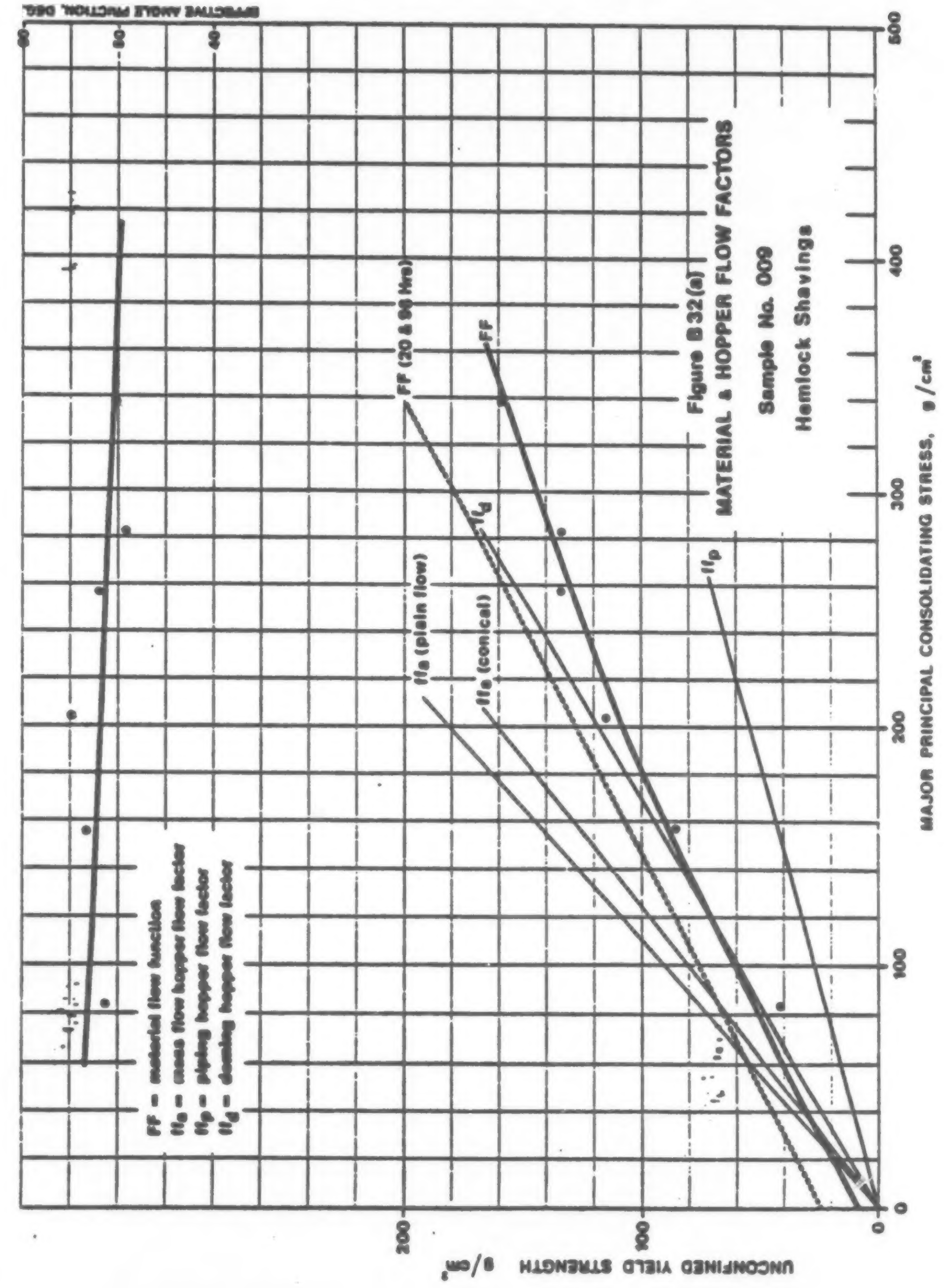

Figure B32(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 009
Hemlock Shavings

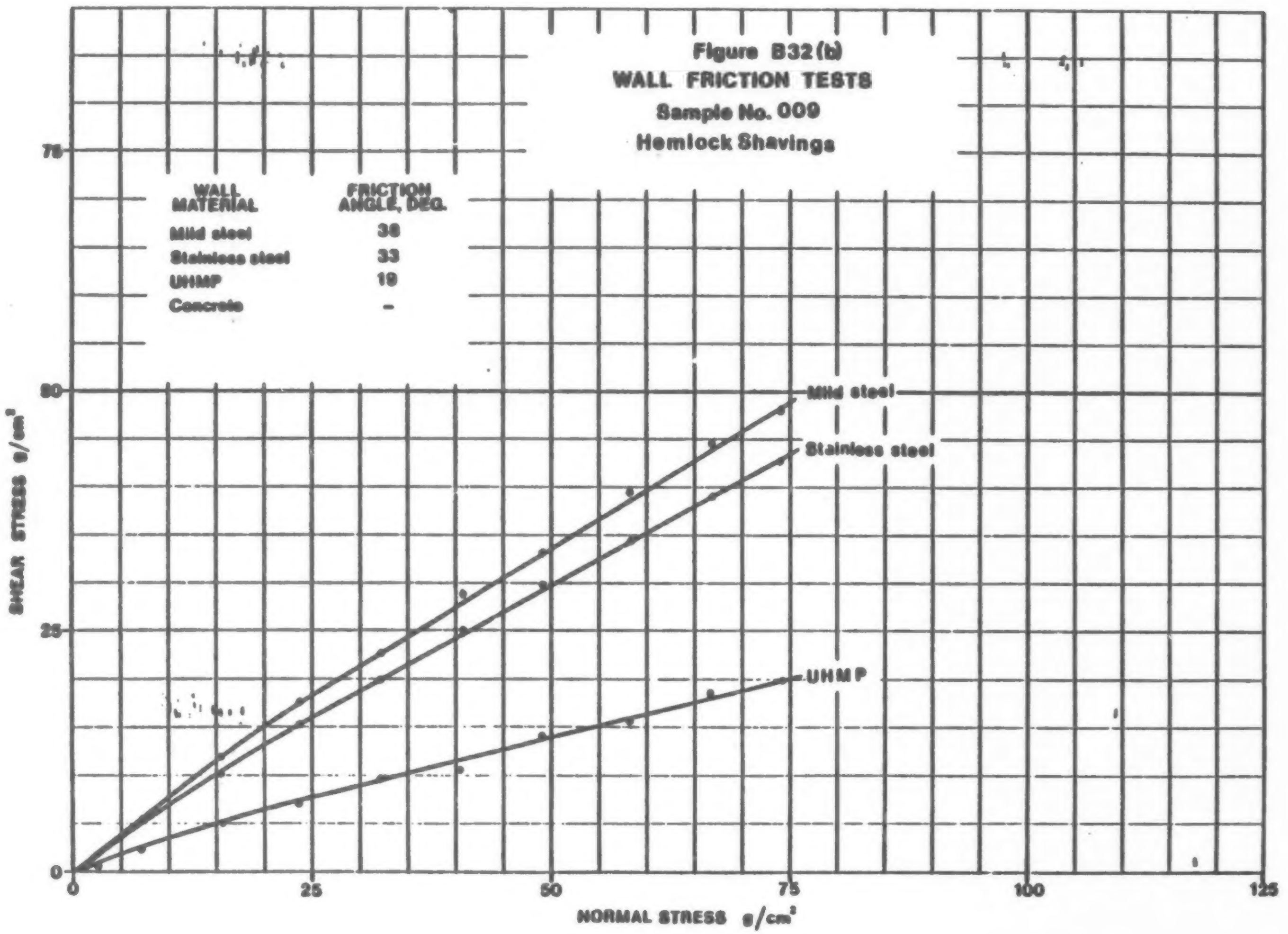

Figure B32(b)
WALL FRICTION TESTS
Sample No. 009
Hemlock Shavings

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	38
Stainless steel	33
UHMP	19
Concrete	-

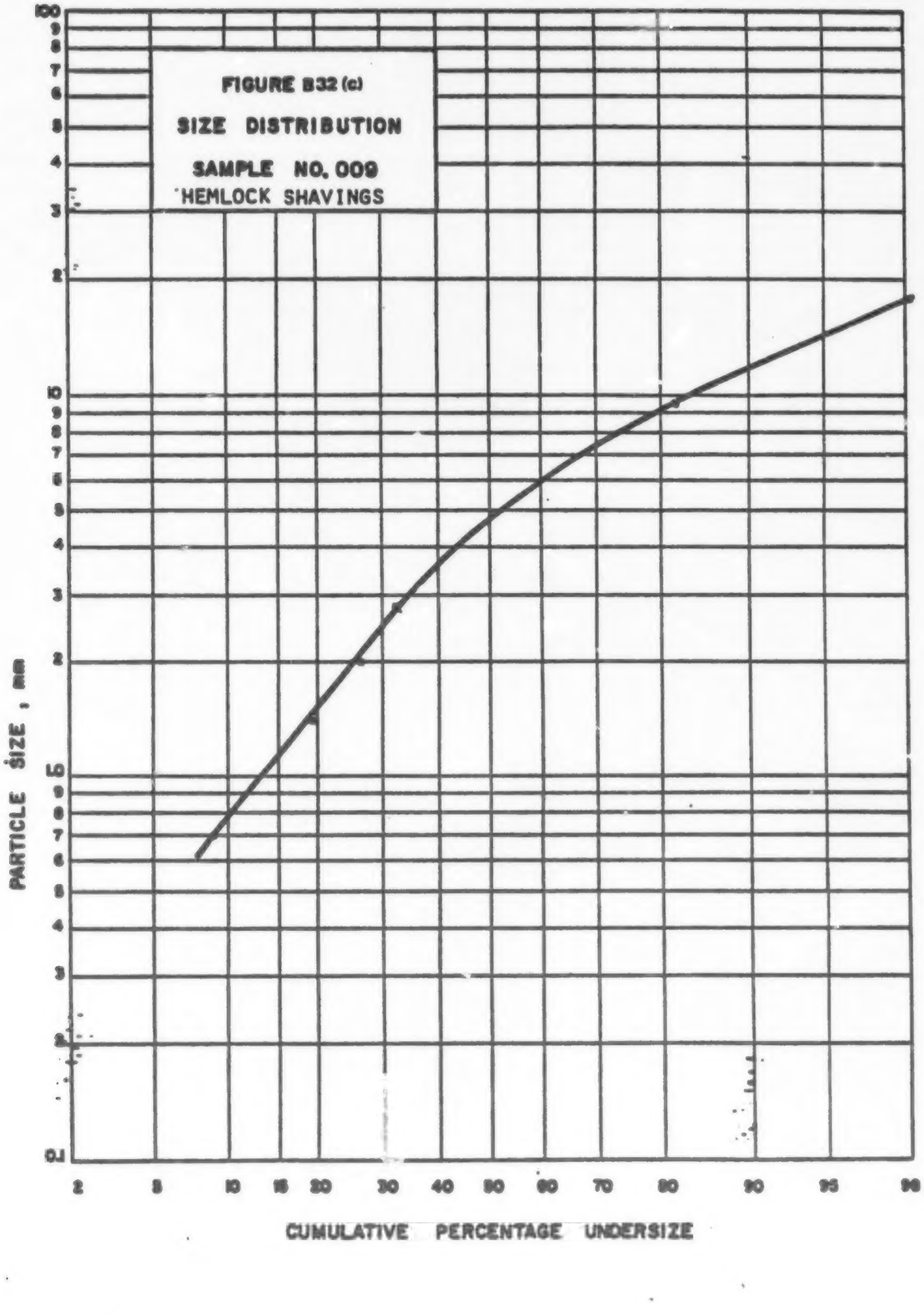

FIGURE B32 (c)

SIZE DISTRIBUTION

SAMPLE NO. 009

HEMLOCK SHAVINGS

TABLE B33 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK SAWDUST (CANFOR-EBURNE) SAMPLE # 010

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	19.1		
		1.5	6.0
		2.9	7.5
		4.3	9.3
		6.2	11.9
		11.8	16.4
		13.2	17.9
		14.6	19.1
24.3	27.8		
		1.5	4.6
		2.9	6.5
		4.3	8.5
		9.0	13.6
		14.6	18.9
		21.0	24.2
		24.3	27.8
45.0	52.6		
		1.5	5.3
		2.9	9.3
		4.3	10.0
		9.0	16.4
		18.2	26.3
		33.9	42.3
		45.0	52.6
60.3	72.6		
		1.5	5.7
		2.9	8.3
		4.3	9.4
		9.0	17.5
		24.3	36.5
		45.0	59.5
		60.3	72.6
85.6	98.7		
		1.5	6.8
		4.3	10.6
		9.0	19.6
		45.0	62.2
		60.3	78.0
		70.4	86.7
		85.6	98.7
115.9	136.4		
		1.5	7.4
		4.3	14.7
		9.0	22.1
		24.3	43.6
		60.3	84.6
		85.6	109.1
		115.9	136.4

TABLE B33 (b)

HEMLOCK SAWDUST (CANFOR-EBURNE) SAMPLE # 010 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	19.1	46.5	16.5	2.82	58.6	59.98	1.95	.59
24.3	27.8	63.8	15.1	4.22	52.5	59.98	1.79	.54
45.0	52.6	120.0	29.5	4.06	53.0	59.98	3.49	1.06
60.3	72.6	164.8	42.8	3.85	53.8	59.98	5.06	1.54
85.6	98.7	229.1	56.9	4.03	53.2	59.98	6.72	2.04
115.9	136.4	311.6	78.1	3.99	53.3	59.98	9.23	2.81

SHEAR INDEX (N) = 1.40

YIELD LOCUS	PERCENT FIT
1	99.6
2	100.0
3	99.8
4	99.5
5	99.8
6	99.8

TABLE B33 (c)

WALL FRICTION TEST RESULTS

HEMLOCK SAWDUST (CANFOR - EBURNE) SAMPLE 010

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	66.0
150.5	56.1
122.5	46.3
94.4	37.9
66.3	26.7
52.3	23.9
38.3	18.2
24.2	12.6
10.2	7.0
5.0	4.2

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	103.8
150.5	88.4
122.5	73.0
94.4	58.9
66.3	43.5
52.3	35.1
38.3	26.7
24.2	18.2
10.2	8.4
5.0	5.6

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	39.3
150.5	32.3
122.5	26.7
94.4	21.0
66.3	15.4
52.3	12.6
38.3	9.8
24.2	7.0
10.2	2.8
5.0	1.4

TABLE B33 (c) con't

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	116.5
150.5	101.0
122.5	85.6
94.4	67.4
66.3	49.1
52.3	40.7
38.3	30.9
24.2	21.0
10.2	9.8
5.0	7.0

TABLE B33 (d)

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COMPUTER ANALYSIS OF STORAGE AT REST

HEMLOCK SAWDUST SAMPLE # 010

                                        - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT      <---------------FLOW PROPERTIES---------------->

NORMAL  SHEAR    NORMAL  SHEAR    MAJ PRINC        UNCONFIN  EFFECT   INTERNAL  COHESION
STRESS  STRESS   STRESS  STRESS   CONSOL'N         YIELD     FRIC     FRIC ANG
                                    STRESS         STRESS    ANGLE    AT FREE
                                  INST     TIME                        SURFACE

G/SQ CM G/SQ CM  G/SQ CM G/SQ CM  G/SQ CM          G/SQ CM    DEG       DEG     G/SQ CM


CONSOLIDATION PERIOD  2 HOURS

  15.3    16.4     15.3    14.2    46.5    33.7     4.9      46.1      60.3       .57
  24.2    28.9     24.2    24.5    63.8    57.8    10.5      49.1      60.3      1.22
  44.9    51.5     44.9    46.6   120.0   109.6    21.2      50.0      60.3      2.48

CONSOLIDATION PERIOD  15 HOURS

  44.9    53.2     44.9    42.8   120.0   101.4    15.9      47.2      60.3      1.85

CONSOLIDATION PERIOD  23 HOURS

  85.5    86.7     85.5    72.0   164.8   174.4    19.7      43.1      60.3      2.30

CONSOLIDATION PERIOD  67 HOURS

  44.9    50.5     44.9    38.7   120.0    93.3    11.3      43.9      60.3      1.32


                         SHEAR INDEX (N)   =   1.40

                         COHESION/ TENSILE
                                  STRENGTH =   3.31
```

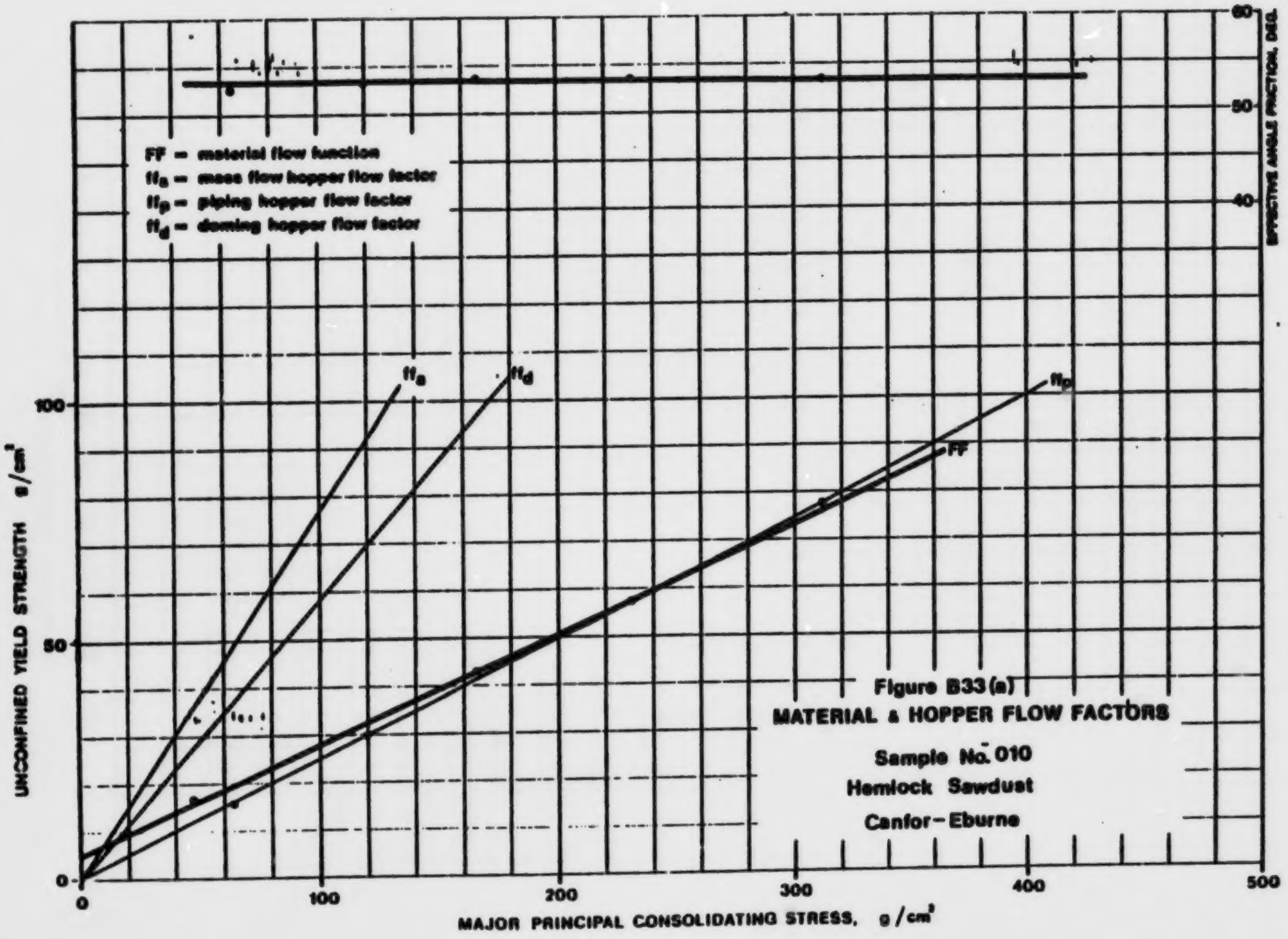

Figure B33(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 010
Hemlock Sawdust
Canfor-Eburne

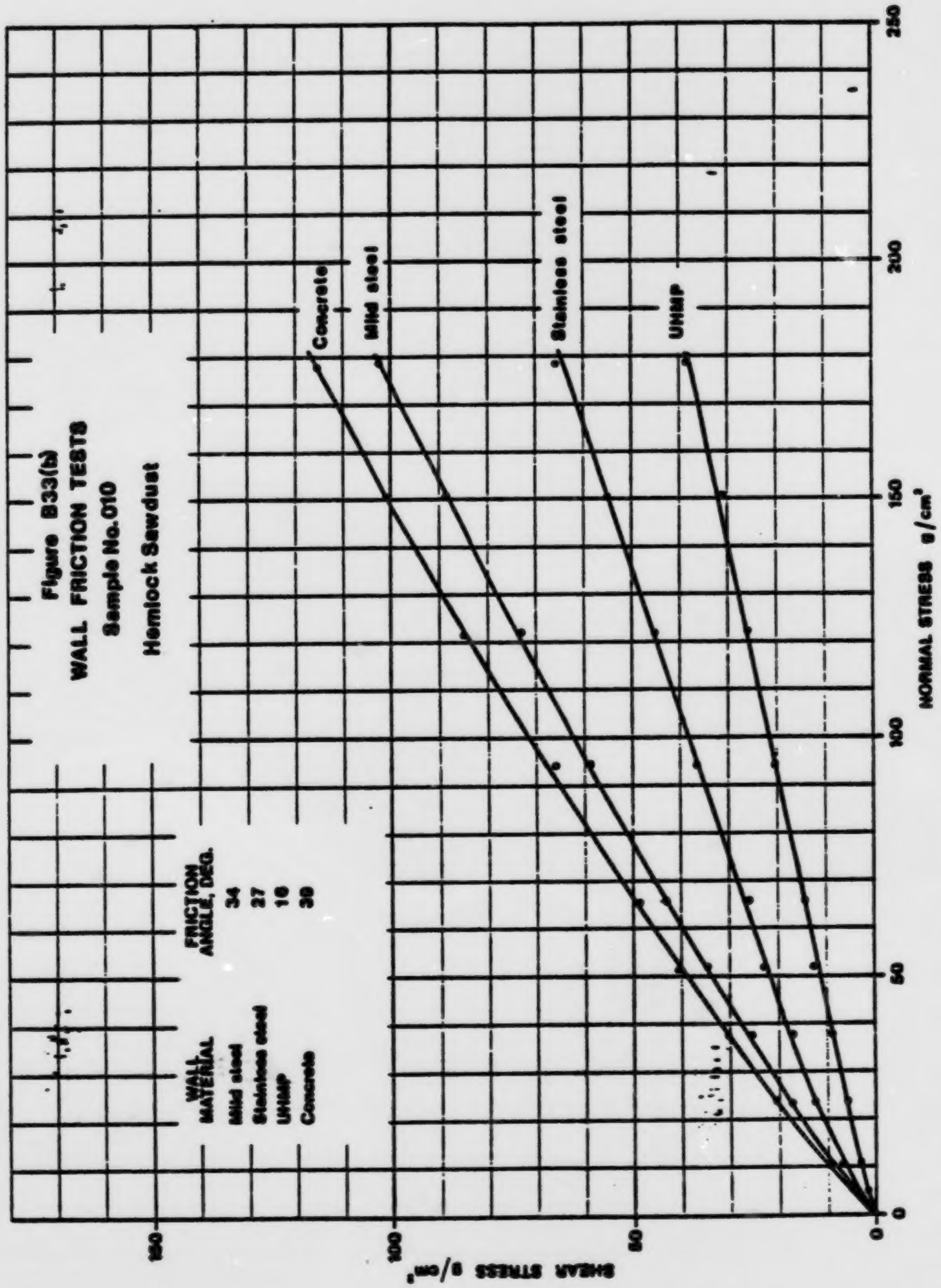

Figure B33(b)
WALL FRICTION TESTS
Sample No.010
Hemlock Sawdust

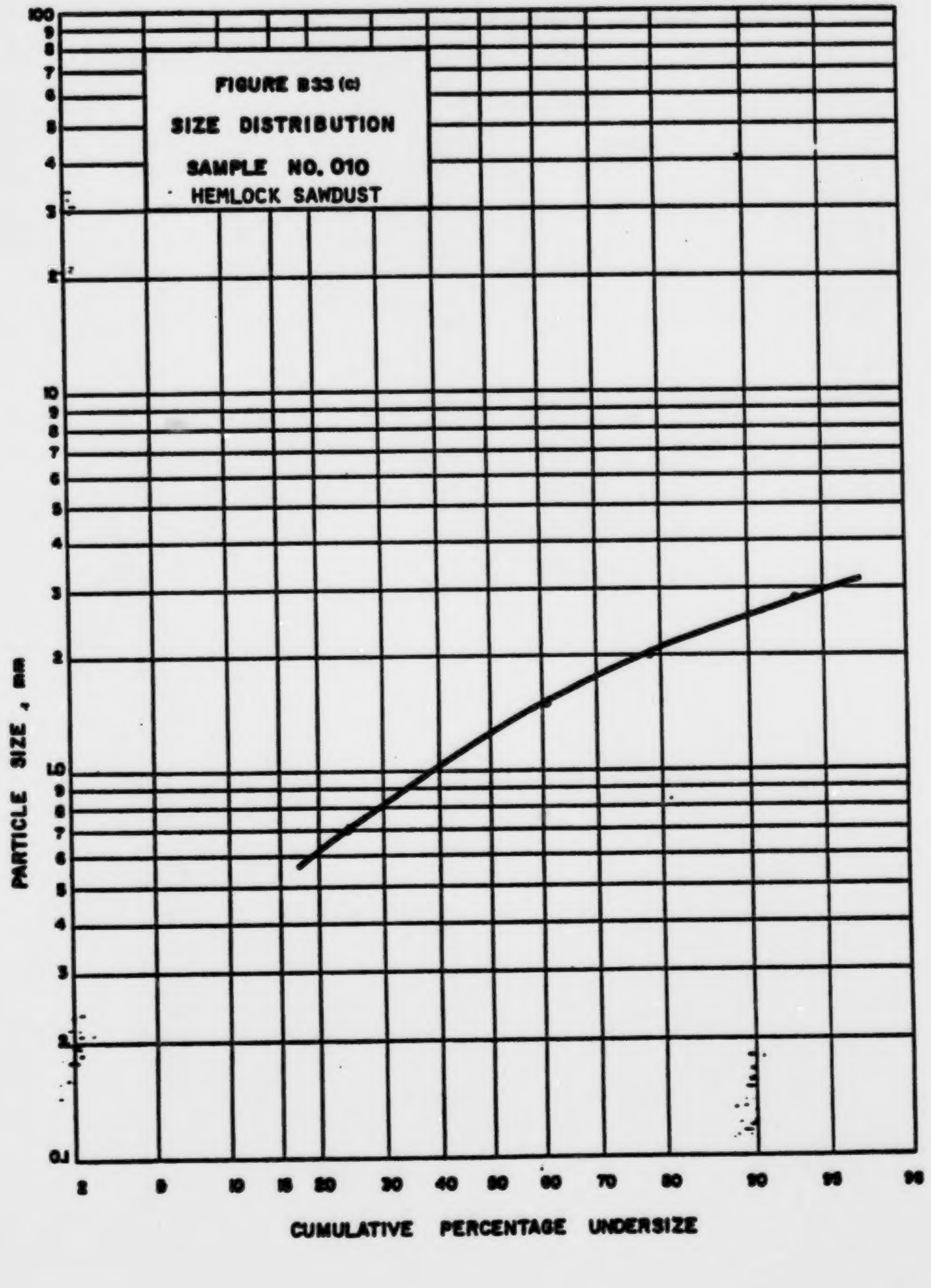

FIGURE B33 (c)

SIZE DISTRIBUTION

SAMPLE NO. 010

HEMLOCK SAWDUST

TABLE B34 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CYPRESS SAWDUST (TERMINAL SAW MILLS) SAMPLE # 012

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	15.0		
		1.5	3.8
		2.9	5.2
		4.3	8.5
		6.2	9.2
		11.8	13.9
		13.2	13.9
		14.6	15.0
24.3	23.7		
		1.5	4.6
		2.9	7.5
		4.3	8.5
		9.0	16.1
		14.6	19.6
		21.0	24.8
		24.3	23.7
45.0	45.3		
		1.5	5.3
		2.9	7.0
		4.3	8.5
		9.0	13.9
		18.2	24.5
		33.9	39.5
		45.0	45.3
60.3	60.6		
		1.5	6.2
		2.9	8.3
		4.3	12.3
		9.0	20.7
		24.3	37.9
		45.0	48.0
		60.3	60.6
85.6	91.1		
		1.5	6.0
		4.3	13.3
		9.0	19.6
		45.0	57.8
		60.3	74.7
		70.4	78.0
		85.6	91.1
115.9	121.1		
		1.5	5.3
		4.3	12.3
		9.0	23.7
		24.3	51.8
		60.3	76.4
		85.6	97.1
		115.9	121.1

TABLE B34 (b)

CYPRESS SAWDUST (TERMINAL SAW MILLS) SAMPLE # 012 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	15.0	35.4	11.8	2.99	51.9	55.11	1.61	.53
24.3	23.7	59.9	20.6	2.90	52.4	55.11	2.80	.92
45.0	45.3	102.8	30.0	3.43	49.4	55.11	4.08	1.34
60.3	60.6	139.6	42.0	3.32	50.0	55.11	5.71	1.88
85.6	91.1	204.5	66.0	3.10	51.2	55.11	8.97	2.95
115.9	121.1	271.9	84.4	3.22	50.5	55.11	11.47	3.77

SHEAR INDEX (N) = 1.48

YIELD LOCUS	PERCENT FIT
1	99.5
2	99.1
3	99.4
4	99.4
5	99.6
6	99.3

TABLE B34 (c)

WALL FRICTION TEST RESULTS

CYPRESS SAWDUST (TERMINAL SAWMILLS) SAMPLE 012

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	63.9
150.4	54.3
122.3	45.6
94.3	37.5
66.2	26.7
52.2	21.8
38.1	18.0
24.1	11.2
10.1	5.6
4.8	2.1

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	94.0
150.4	80.7
122.3	66.7
94.3	52.6
66.2	38.6
52.2	31.6
38.1	23.6
24.1	15.4
10.1	7.3
4.8	3.5

WALL MATERIAL - RUSTY MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	110.2
150.4	93.3
122.3	76.5
94.3	60.3
66.2	44.2
52.2	35.1
38.1	26.0
24.1	16.8
10.1	7.7
4.8	3.5

TABLE B34 (c) con't

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	36.5
150.4	31.6
122.3	26.7
94.3	21.8
66.2	16.1
52.2	13.3
38.1	9.8
24.1	7.0
10.1	3.5
4.8	2.1

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	121.4
150.4	103.1
122.3	82.8
94.3	63.1
66.2	44.9
52.2	35.8
38.1	26.7
24.1	17.5
10.1	8.4
4.8	4.2

TABLE B34 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

CYPRESS SAWDUST SAMPLE # 012

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<———FLOW PROPERTIES———					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS		UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
				INST	TIME				
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 2 HOURS									
24.2	24.0	24.2	28.1	59.9	64.1	25.2	55.0	55.2	3.43
85.5	79.6	85.5	90.0	204.5	206.5	67.7	51.6	55.2	9.18
CONSOLIDATION PERIOD 44 HOURS									
85.5	78.6	85.5	96.6	204.5	220.4	82.7	54.1	55.2	11.23
CONSOLIDATION PERIOD 90 HOURS									
24.2	21.5	24.2	28.4	59.9	64.7	25.9	55.4	55.2	3.52

SHEAR INDEX (N) = 1.48

COHESION/ TENSILE STRENGTH = 3.04

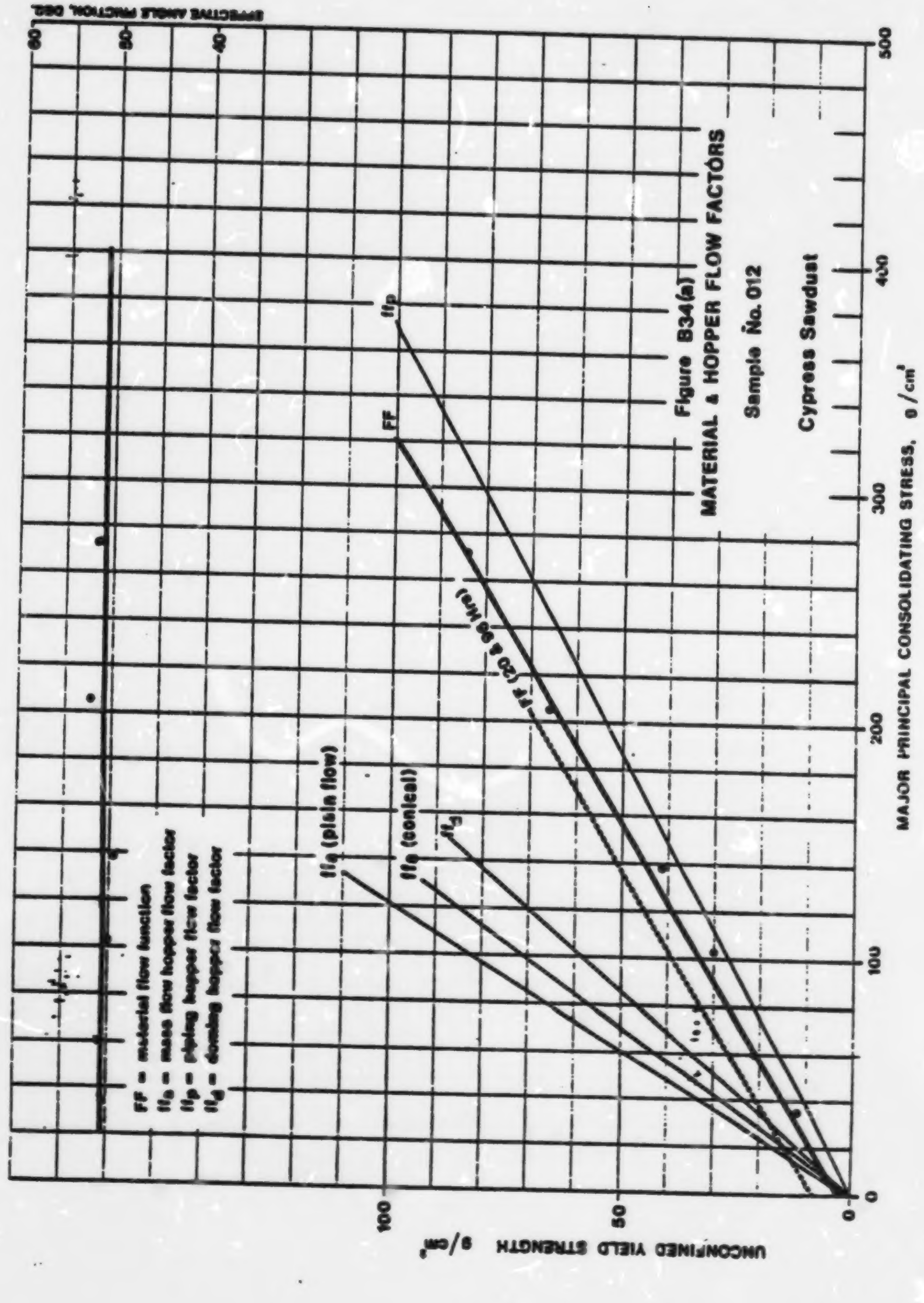

Figure B34(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 012

Cypress Sawdust

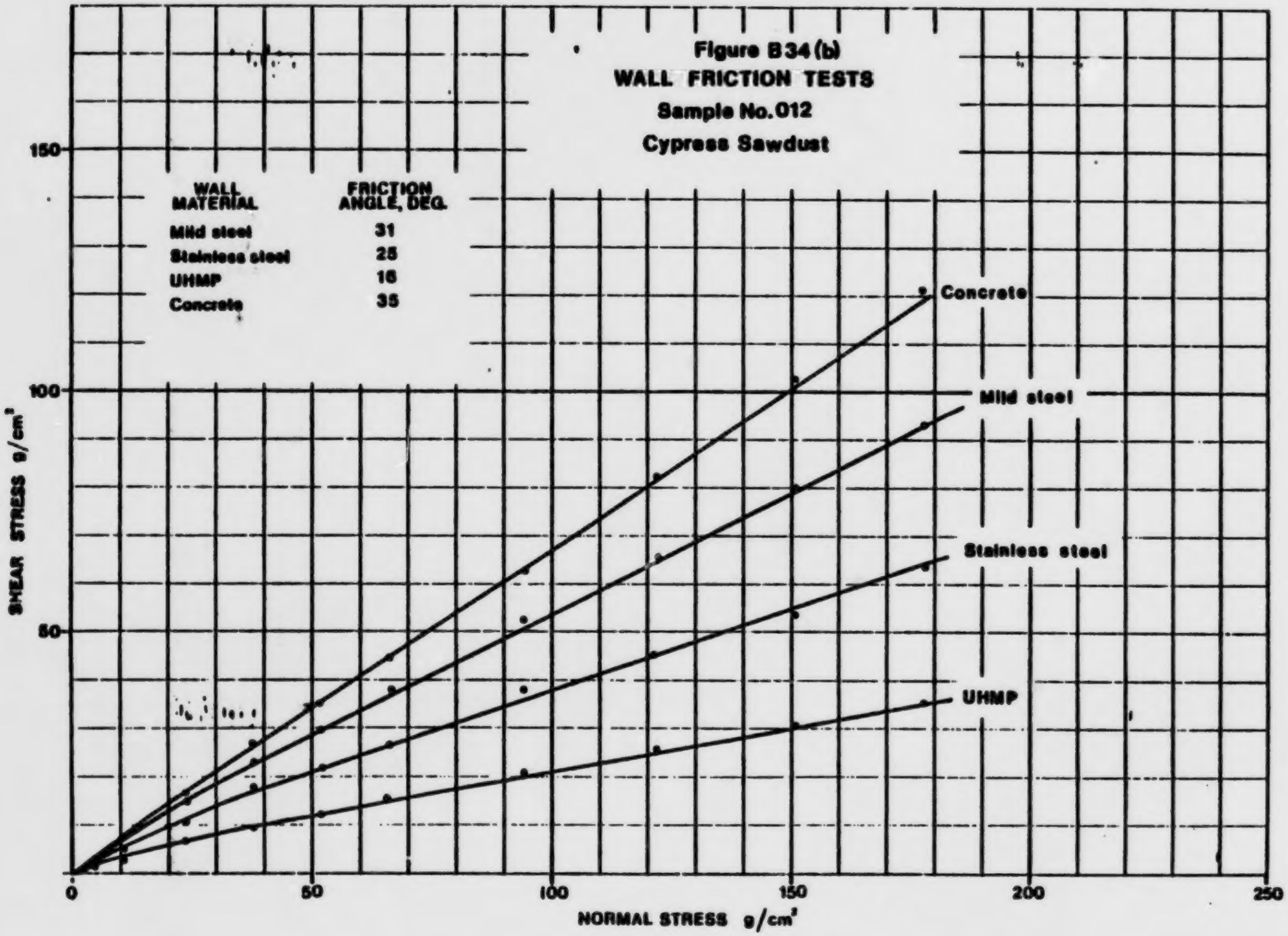

Figure B34 (b)
WALL FRICTION TESTS
Sample No. 012
Cypress Sawdust

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	31
Stainless steel	25
UHMP	16
Concrete	35

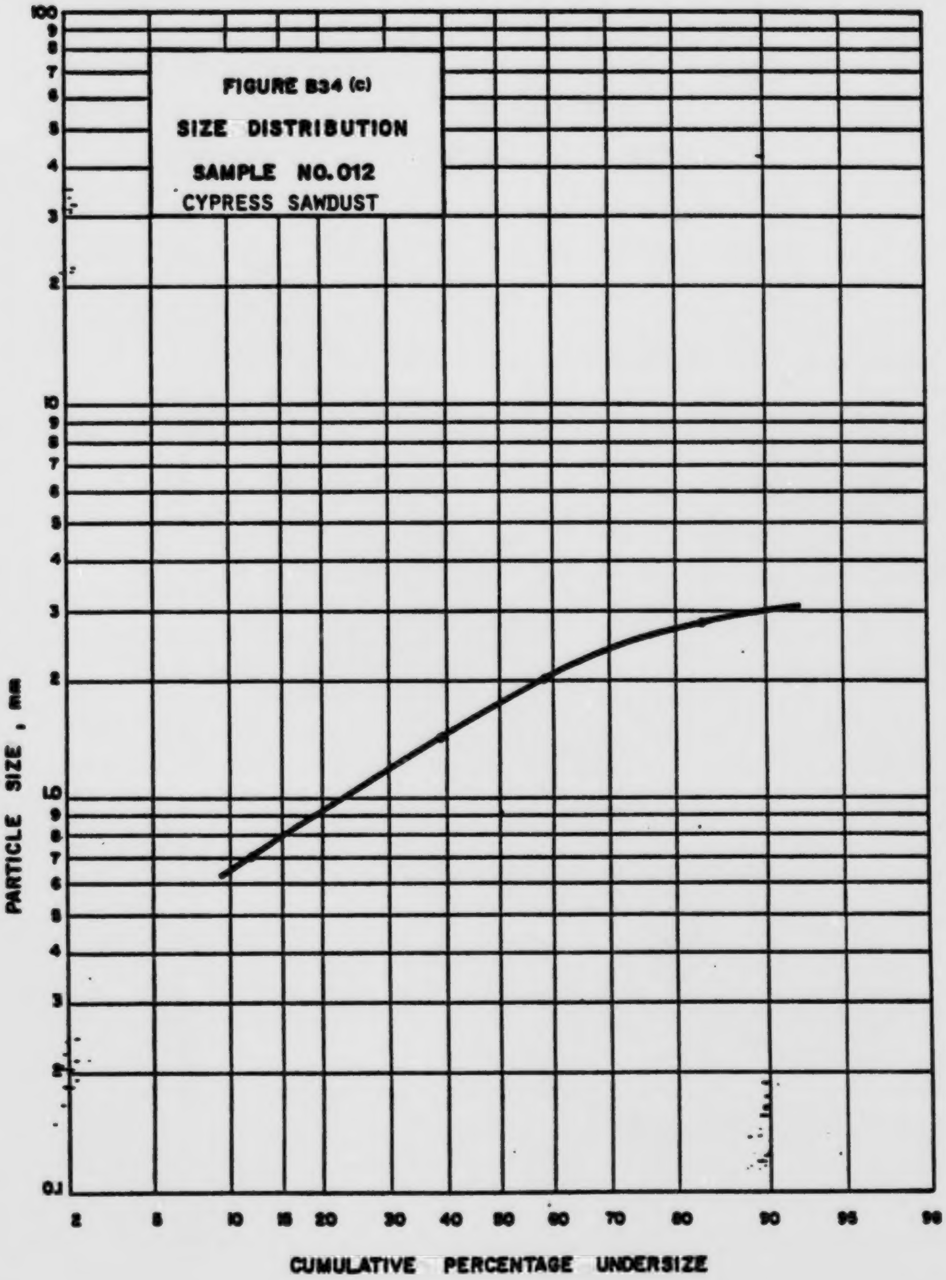

FIGURE B34 (c)

SIZE DISTRIBUTION

SAMPLE NO. 012

CYPRESS SAWDUST

TABLE B35 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR SAWDUST (MB-C.WHITE PINE DIV.) SAMPLE # 014

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	15.8		
		1.5	4.0
		2.9	5.3
		4.3	6.8
		6.2	9.4
		11.8	11.2
		13.2	13.5
		14.6	15.8
24.3	27.3		
		1.5	4.1
		2.9	6.4
		4.3	8.4
		9.0	14.5
		14.6	19.4
		21.0	24.3
		24.3	27.3
45.0	52.4		
		1.5	4.9
		2.9	7.4
		4.3	9.7
		9.0	16.9
		18.2	28.5
		33.9	43.6
		45.0	52.4
60.3	64.9		
		1.5	6.0
		2.9	9.0
		4.3	11.3
		9.0	16.9
		24.3	32.3
		45.0	51.8
		60.3	64.9
85.6	96.0		
		1.5	5.7
		4.3	11.2
		9.0	18.3
		45.0	55.1
		60.3	71.5
		70.4	84.0
		85.6	96.0
115.9	121.6		
		1.5	7.9
		4.3	12.0
		9.0	24.0
		24.3	49.1
		60.3	79.1
		85.6	103.6
		115.9	121.6

TABLE B35 (b)

CEDAR SAWDUST (MB-C.WHITE PINE DIV.) SAMPLE # 014 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	15.8	35.5	7.0	5.06	49.6	58.25	.89	.31
24.3	27.3	64.3	15.7	4.10	52.4	58.25	1.99	.68
45.0	52.4	122.1	31.7	3.85	53.3	58.25	4.03	1.38
60.3	64.9	150.2	31.5	4.77	50.4	58.25	4.01	1.37
85.6	96.0	218.8	49.0	4.46	51.2	58.26	6.23	2.13
115.9	121.6	294.3	64.9	4.53	51.0	58.25	8.26	2.83

SHEAR INDEX (N) = 1.38

YIELD LOCUS	PERCENT FIT
1	98.9
2	99.9
3	99.8
4	99.9
5	99.7
6	99.7

TABLE B35 (c)

WALL FRICTION TEST RESULTS

CEDAR SAWDUST (MB - WHITE PINE DIV.) SAMPLE 014

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	103.8
150.4	89.8
122.3	73.7
94.3	58.2
66.2	41.4
52.2	33.7
38.1	25.3
24.1	16.1
10.1	7.7
4.8	4.2

WALL MATERIAL - RUSTY MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	116.5
150.4	99.6
122.3	82.1
94.3	63.1
66.2	44.9
52.2	34.4
38.1	26.0
24.1	16.1
10.1	7.7
4.8	4.2

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	76.5
150.4	66.0
122.3	54.7
94.3	44.2
66.2	31.6
52.2	26.0
38.1	20.3
24.1	13.3
10.1	6.3
4.8	3.5

TABLE B35 (c) con't

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	35.1
150.4	29.5
122.3	24.6
94.3	19.6
66.2	14.0
52.2	11.9
38.1	9.1
24.1	6.3
10.1	3.5
4.8	2.1

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	126.3
150.4	109.5
122.3	89.8
94.3	68.8
66.2	47.7
52.2	37.9
38.1	27.4
24.1	18.2
10.1	8.4
4.8	3.5

TABLE B35 (d)

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COMPUTER ANALYSIS OF STORAGE AT REST

CEDAR SAWDUST SAMPLE # 014

                        - TIME CONSOLIDATION RESULTS

CONSOLIDATION   YIELD POINT    <---------------FLOW PROPERTIES------------------>

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC      UNCONFIN  EFFECT  INTERNAL COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N       YIELD     FRIC    FRIC ANG
                                  STRESS       STRESS    ANGLE   AT FREE
                                INST   TIME                        SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM       G/SQ CM    DEG      DEG    G/SQ CM

CONSOLIDATION PERIOD  20 HOURS

  24.2    22.9    24.2    28.6   64.3   67.3   19.0      54.1      58.1     2.42
  85.5    10.4    85.5    95.5  218.8  224.3   55.3      52.2      58.1     7.06


                   SHEAR INDEX (N)    =   1.38

                   COHESION/ TENSILE
                           STRENGTH =   2.92
```

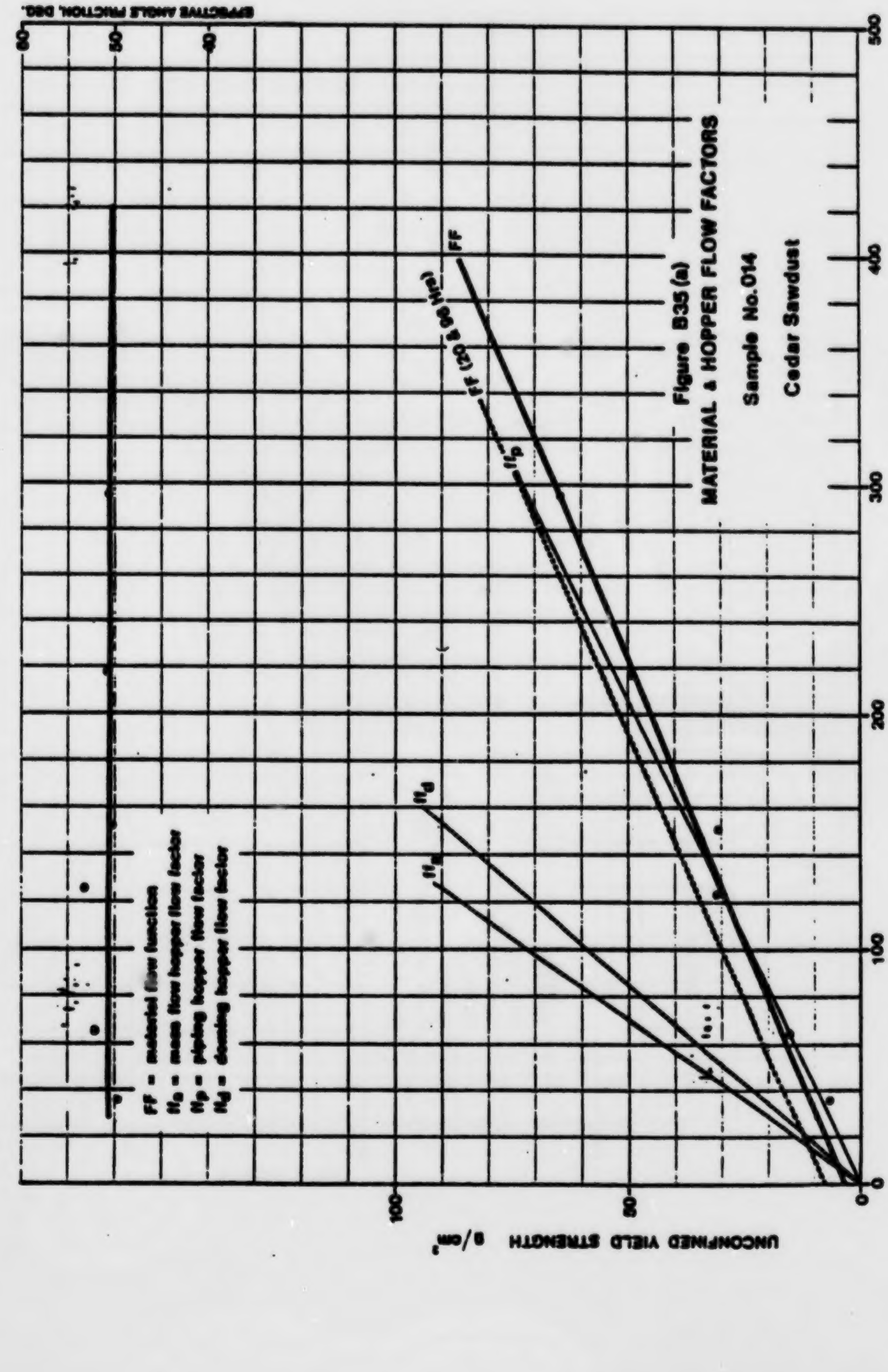

Figure B35 (a)
MATERIAL & HOPPER FLOW FACTORS
Sample No.014
Cedar Sawdust

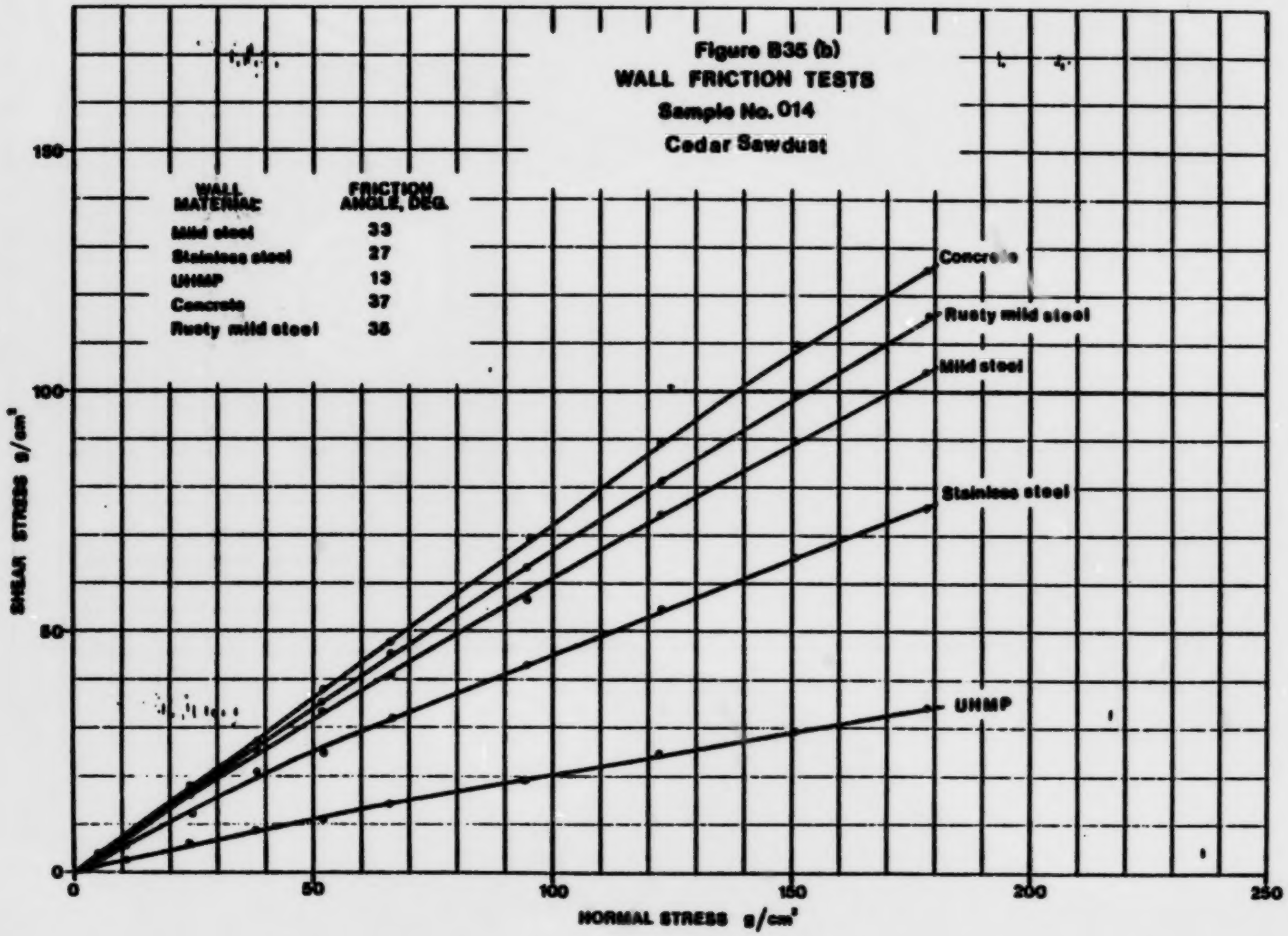

Figure B35 (b)
WALL FRICTION TESTS
Sample No. 014
Cedar Sawdust

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	33
Stainless steel	27
UHMP	13
Concrete	37
Rusty mild steel	35

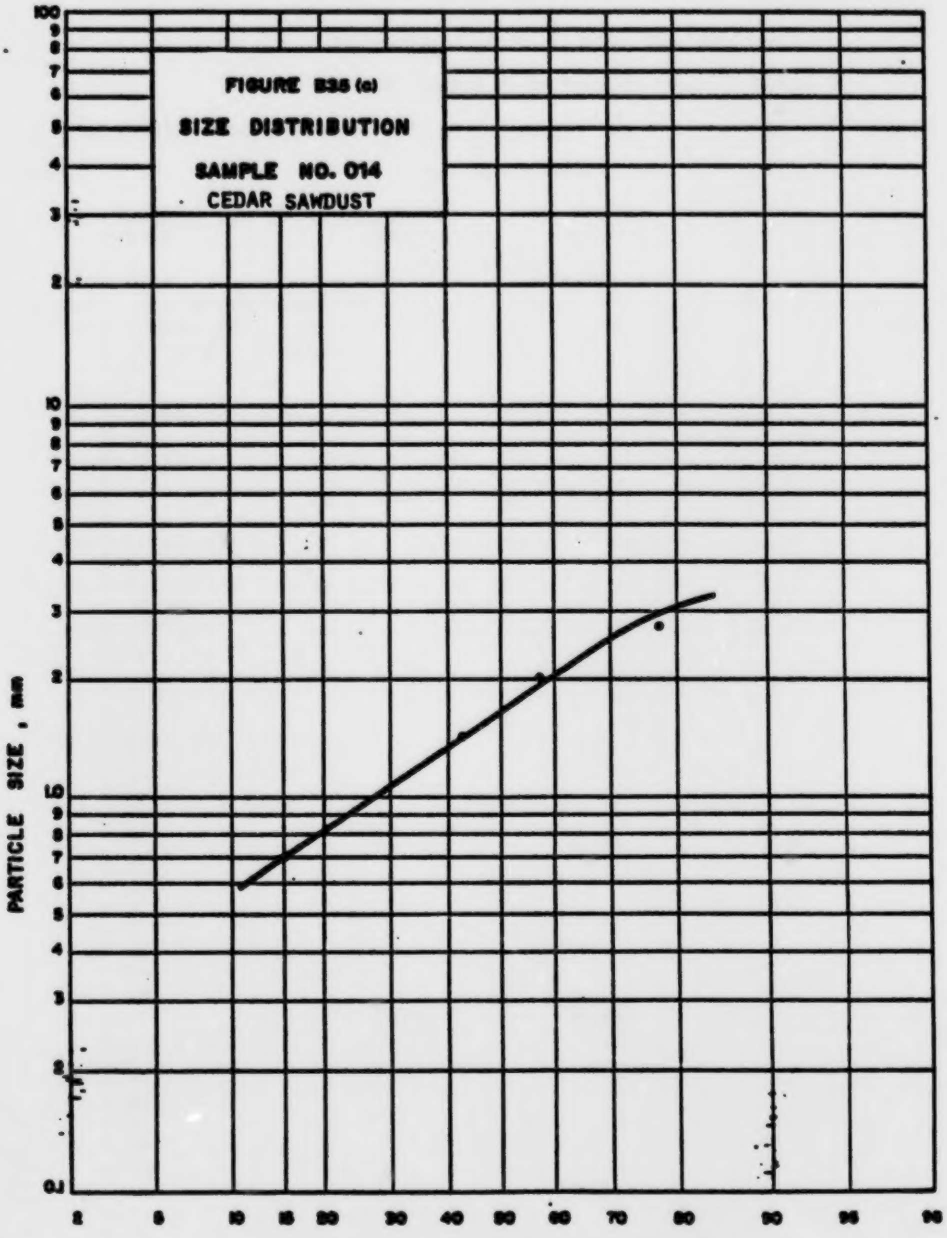

FIGURE B35 (c)
SIZE DISTRIBUTION
SAMPLE NO. 014
CEDAR SAWDUST

TABLE B36 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

SANDER DUST (RICHMOND PLYWOOD) SAMPLE 01B

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	16.1	1.5	4.5
		2.9	6.0
		4.3	7.6
		6.2	9.5
		11.8	13.9
		13.2	14.5
		14.6	16.1
24.3	30.0	1.5	4.7
		2.9	7.0
		4.3	9.1
		9.0	15.5
		14.6	21.3
		21.0	25.6
		24.3	30.0
45.0	53.5	1.5	6.7
		2.9	10.1
		4.3	12.0
		9.0	19.4
		18.2	28.9
		33.9	43.1
		45.0	53.5
60.3	70.9	1.5	7.1
		2.9	10.7
		4.3	13.5
		9.0	22.1
		24.3	40.4
		45.0	58.9
		60.3	70.9
85.6	99.3	1.5	8.3
		4.3	14.5
		9.0	22.9
		45.0	61.6
		60.3	77.5
		70.4	87.8
		85.6	99.3
115.9	122.7	1.5	9.0
		4.3	15.9
		9.0	28.1
		24.3	44.2
		60.3	83.5
		85.6	106.4
		115.9	122.7

TABLE B36 (b)

SANDER DUST (RICHMOND PLYWOOD) SAMPLE 018 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	16.1	37.6	10.6	3.55	52.7	58.41	1.31	.40
24.3	30.0	67.6	22.3	3.03	55.3	58.41	2.75	.85
45.0	53.5	122.4	38.7	3.16	54.6	58.41	4.77	1.47
60.3	70.9	164.7	52.6	3.13	54.7	58.41	6.48	2.00
85.6	99.3	226.9	68.0	3.34	53.7	58.41	8.39	2.59
115.9	122.7	292.5	78.8	3.71	52.0	58.41	9.72	3.00

SHEAR INDEX (N) = 1.44

YIELD LOCUS	PERCENT FIT
1	99.8
2	99.8
3	100.0
4	99.9
5	99.9
6	99.8

TABLE B36 (c)

WALL FRICTION TEST RESULTS

SANDER DUST (RICHMOND PLYWOOD) SAMPLE #018

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	54.7
150.1	46.3
122.0	35.8
94.0	28.1
65.9	20.3
51.9	16.1
37.8	11.9
23.8	8.4
9.8	4.2
4.5	2.8

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	105.2
150.1	89.1
122.0	73.7
94.0	57.5
65.9	41.4
51.9	33.0
37.8	25.3
23.8	16.8
9.8	7.7
4.5	4.2

WALL MATERIAL - RUSTY MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	120.7
150.1	102.4
122.0	84.9
94.0	66.7
65.9	46.3
51.9	35.8
37.8	26.7
23.8	16.8
9.8	7.0
4.5	2.8

TABLE B36 (c) con't

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	49.1
150.1	40.7
122.0	32.3
94.0	24.6
65.9	16.8
51.9	13.3
37.8	11.2
23.8	7.7
9.8	3.5
4.5	2.1

TABLE B36 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

SANDER DUST SAMPLE # 018

                        - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT    <---------------FLOW PROPERTIES----------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC      UNCONFIN  EFFECT   INTERNAL COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N       YIELD     FRIC     FRIC ANG
                                  STRESS       STRESS    ANGLE    AT FREE
                                INST   TIME                        SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM       G/SQ CM    DEG       DEG     G/SQ CM

CONSOLIDATION PERIOD  2 HOURS

  44.9   45.8    44.9    51.4  122.4  118.9   36.4      53.8      58.2      4.51
  85.5   90.0    85.5    96.6  226.9  223.5   66.4      53.3      58.2      8.23

CONSOLIDATION PERIOD  17 HOURS

  44.9   43.6    44.9    52.9   67.6  122.5   39.8      54.8      58.2      4.94
  85.5   90.6    85.5   102.0  226.9  236.2   78.5      55.2      58.2      9.73

                  SHEAR INDEX (N)  =   1.44

                  COHESION/ TENSILE
                        STRENGTH =   3.24
```

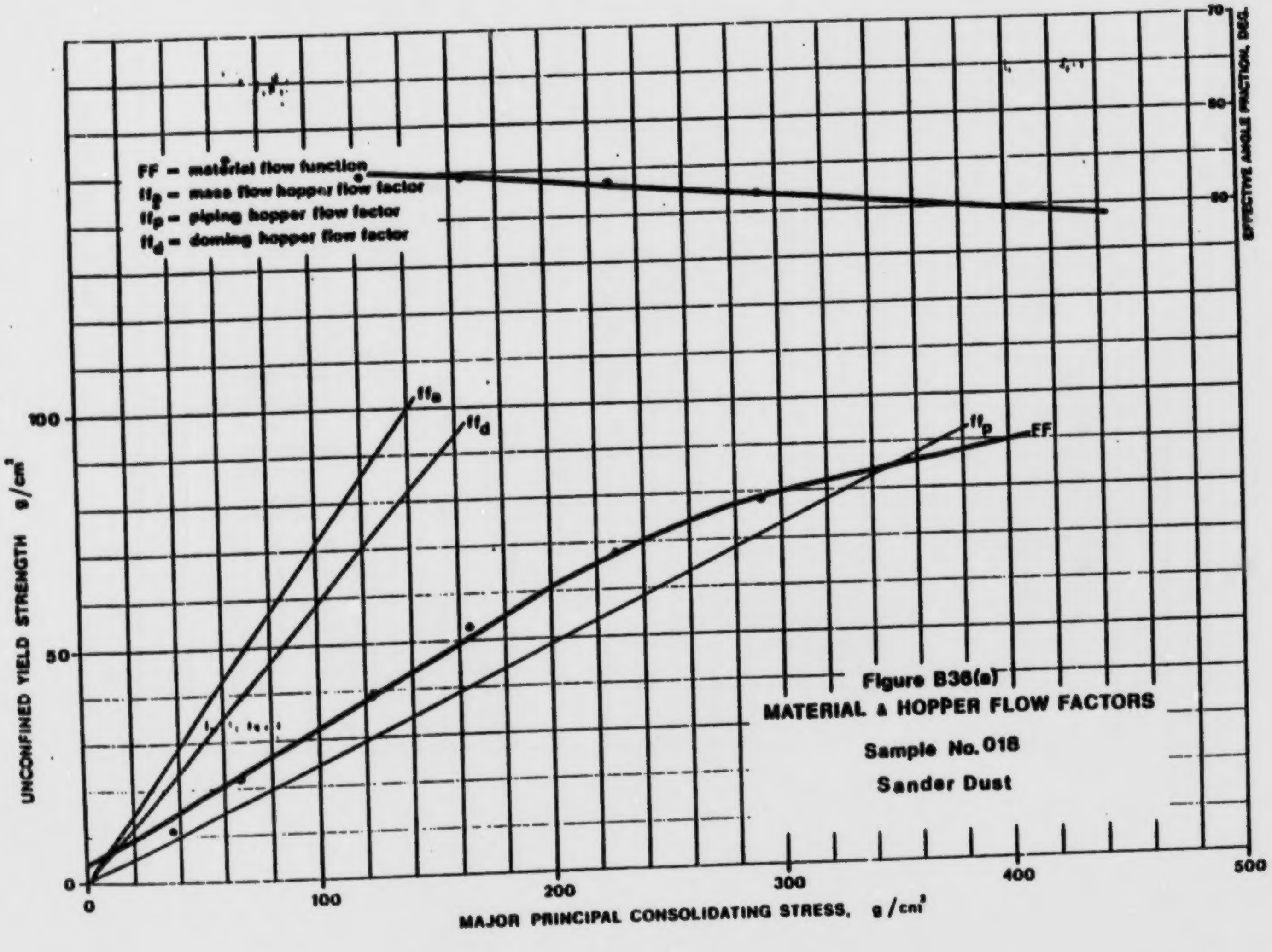

Figure B36(a)

MATERIAL & HOPPER FLOW FACTORS

Sample No. 018

Sander Dust

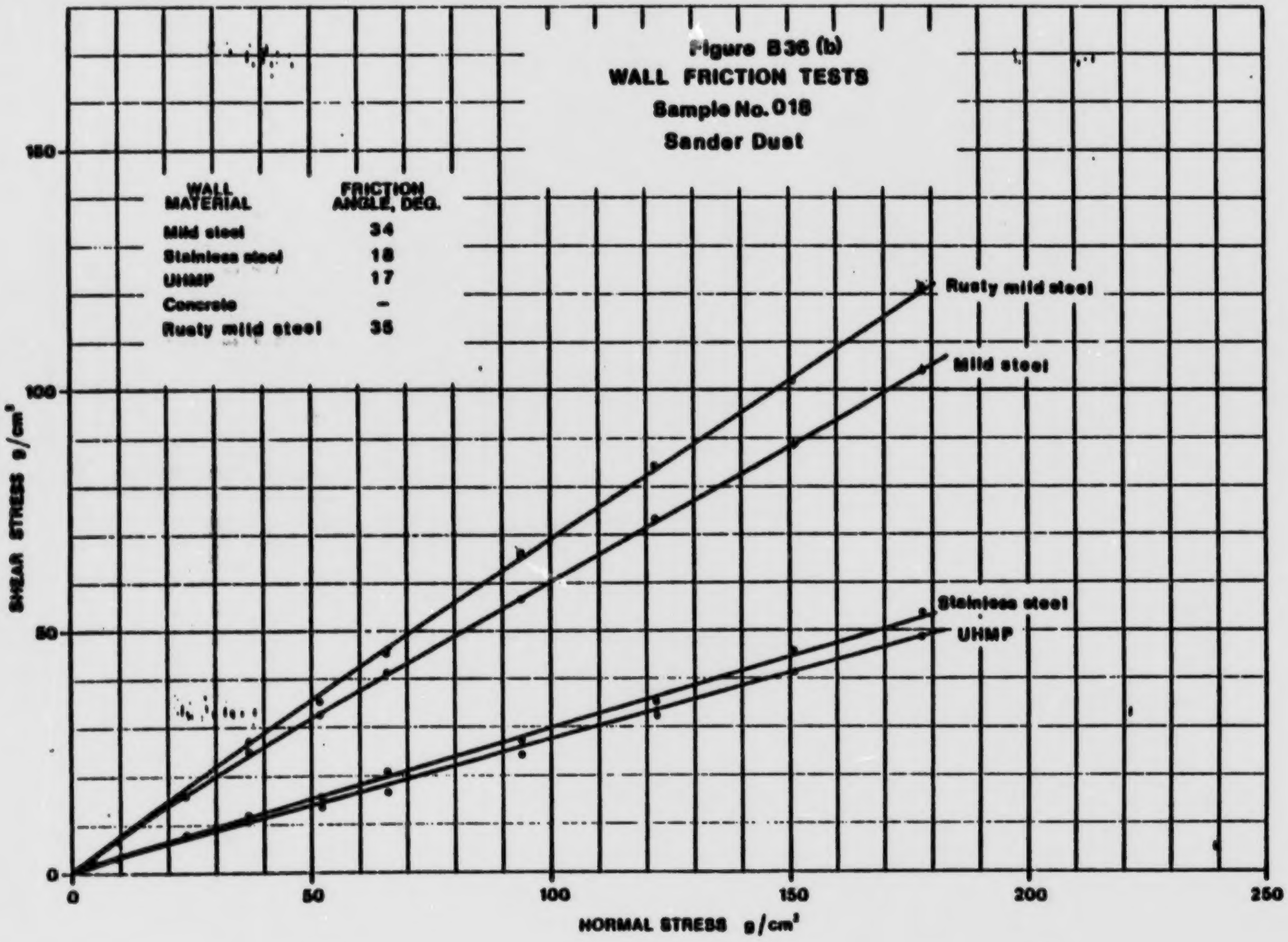

Figure B36 (b)
WALL FRICTION TESTS
Sample No. 018
Sander Dust

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	34
Stainless steel	18
UHMP	17
Concrete	–
Rusty mild steel	35

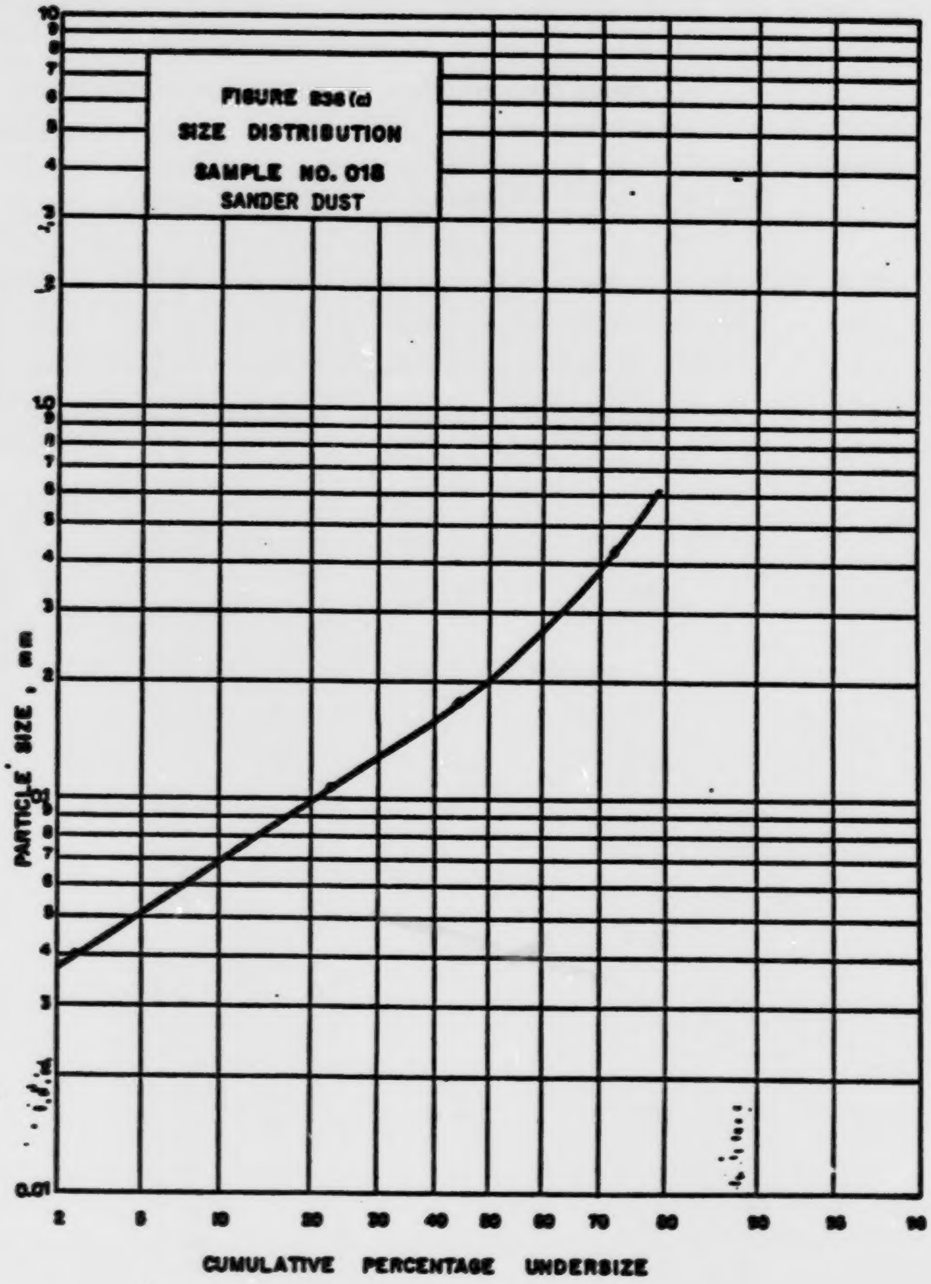

FIGURE B36 (c)
SIZE DISTRIBUTION
SAMPLE NO. 018
SANDER DUST

TABLE B37 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR DUST (KILN DRIED-A&M HUDSON) SAMPLE # 019

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	15.8		
		1.5	3.9
		2.9	5.0
		4.3	7.2
		6.2	8.0
		11.8	12.5
		13.2	14.2
		14.6	15.8
24.3	26.6		
		1.5	4.1
		2.9	6.1
		4.3	7.5
		9.0	12.9
		14.6	18.5
		21.0	23.8
		24.3	26.6
45.0	48.3		
		1.5	5.6
		2.9	7.9
		4.3	10.3
		9.0	17.5
		18.2	27.8
		33.9	40.6
		45.0	48.3
60.3	67.1		
		1.5	7.4
		2.9	9.5
		4.3	11.2
		9.0	17.0
		24.3	36.7
		45.0	56.2
		60.3	67.1
85.6	84.6		
		1.5	7.1
		4.3	11.2
		9.0	19.9
		45.0	61.1
		60.3	70.9
		70.4	75.3
		85.6	84.6
115.9	126.6		
		1.5	8.6
		4.3	13.8
		9.0	21.3
		24.3	39.4
		60.3	78.6
		85.6	99.8
		115.9	126.6

TABLE B37 (b)

CEDAR DUST (KILN DRIED—A&M HUDSON) SAMPLE # 019 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	15.8	36.1	7.8	4.65	50.3	57.82	1.00	.35
24.3	26.6	61.9	14.3	4.34	51.2	57.81	1.84	.64
45.0	48.3	116.0	27.6	4.21	51.6	57.82	3.56	1.24
60.3	67.1	158.2	39.3	4.03	52.2	57.82	5.07	1.76
85.6	84.6	207.7	42.1	4.93	49.5	57.82	5.43	1.89
115.9	126.6	291.1	64.8	4.49	50.7	57.82	8.36	2.91

SHEAR INDEX (N) = 1.38

YIELD LOCUS	PERCENT FIT
1	99.7
2	100.0
3	99.9
4	99.9
5	99.7
6	99.9

TABLE B37 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

CEDAR DUST SAMPLE # 019

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<——FLOW PROPERTIES——>					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS		UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
				INST	TIME				
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 2 HOURS									
44.9	45.8	44.9	49.9	116.0	117.2	29.6	52.2	57.6	3.85
85.5	86.7	85.5	92.2	207.7	216.6	50.7	51.1	57.6	6.59
CONSOLIDATION PERIOD 20 HOURS									
44.9	42.5	44.9	48.3	116.0	113.6	26.6	51.1	57.6	3.45
85.5	89.5	85.5	97.1	207.7	227.9	60.4	52.8	57.6	7.85

SHEAR INDEX (N) = 1.38

COHESION/ TENSILE
STRENGTH = 2.86

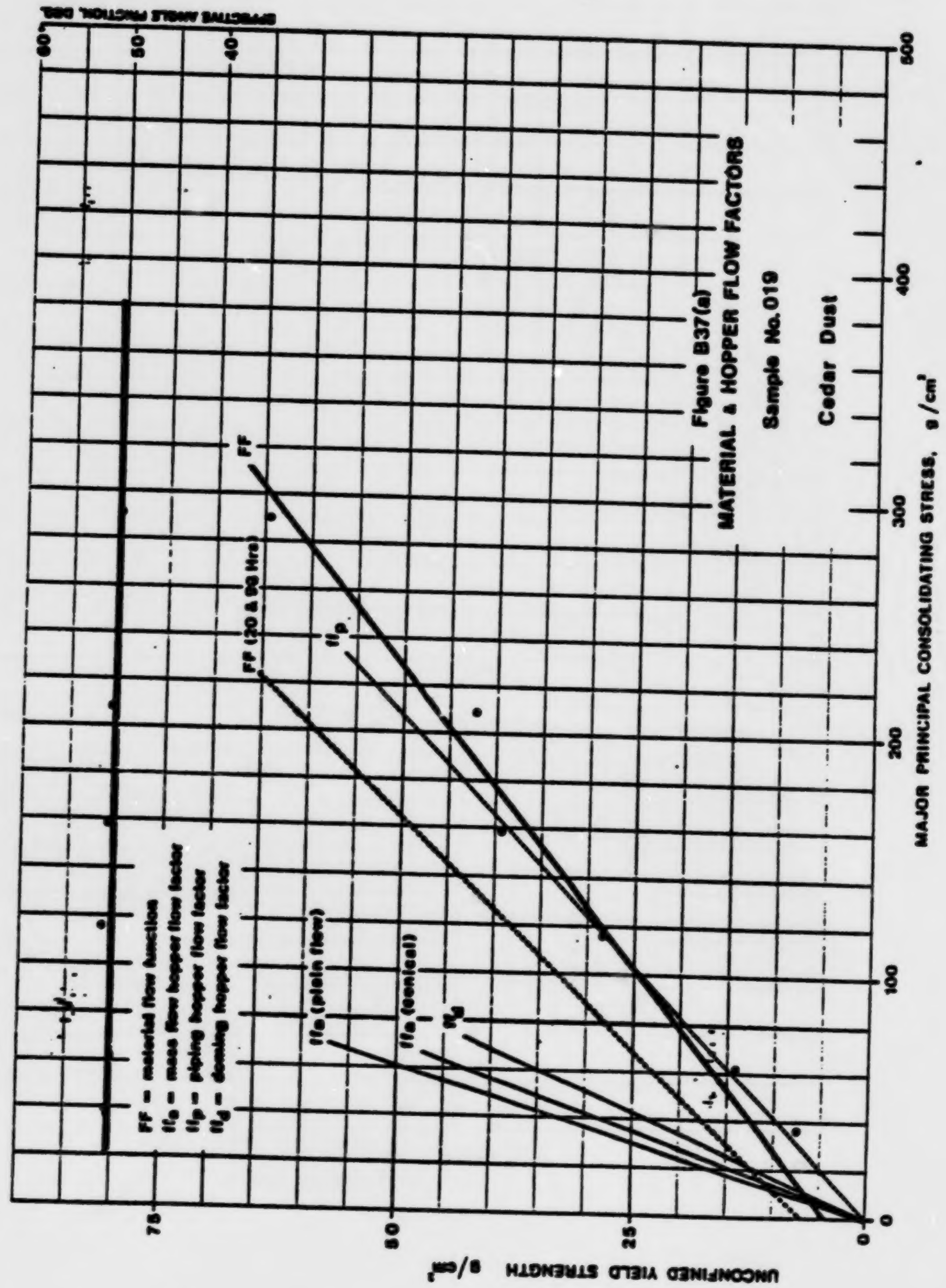

Figure B37(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No.019
Cedar Dust

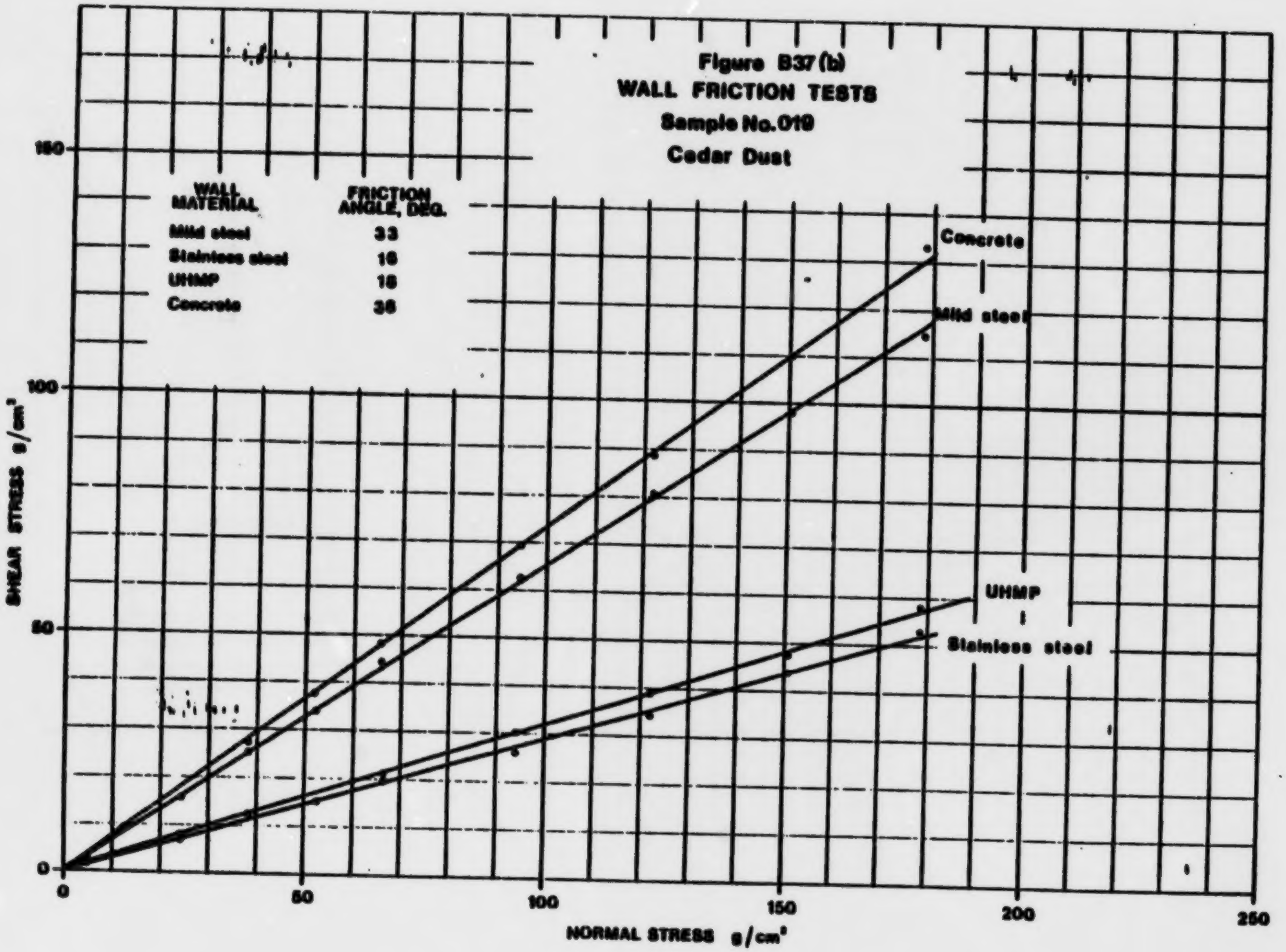

Figure B37(b)
WALL FRICTION TESTS
Sample No. 019
Cedar Dust

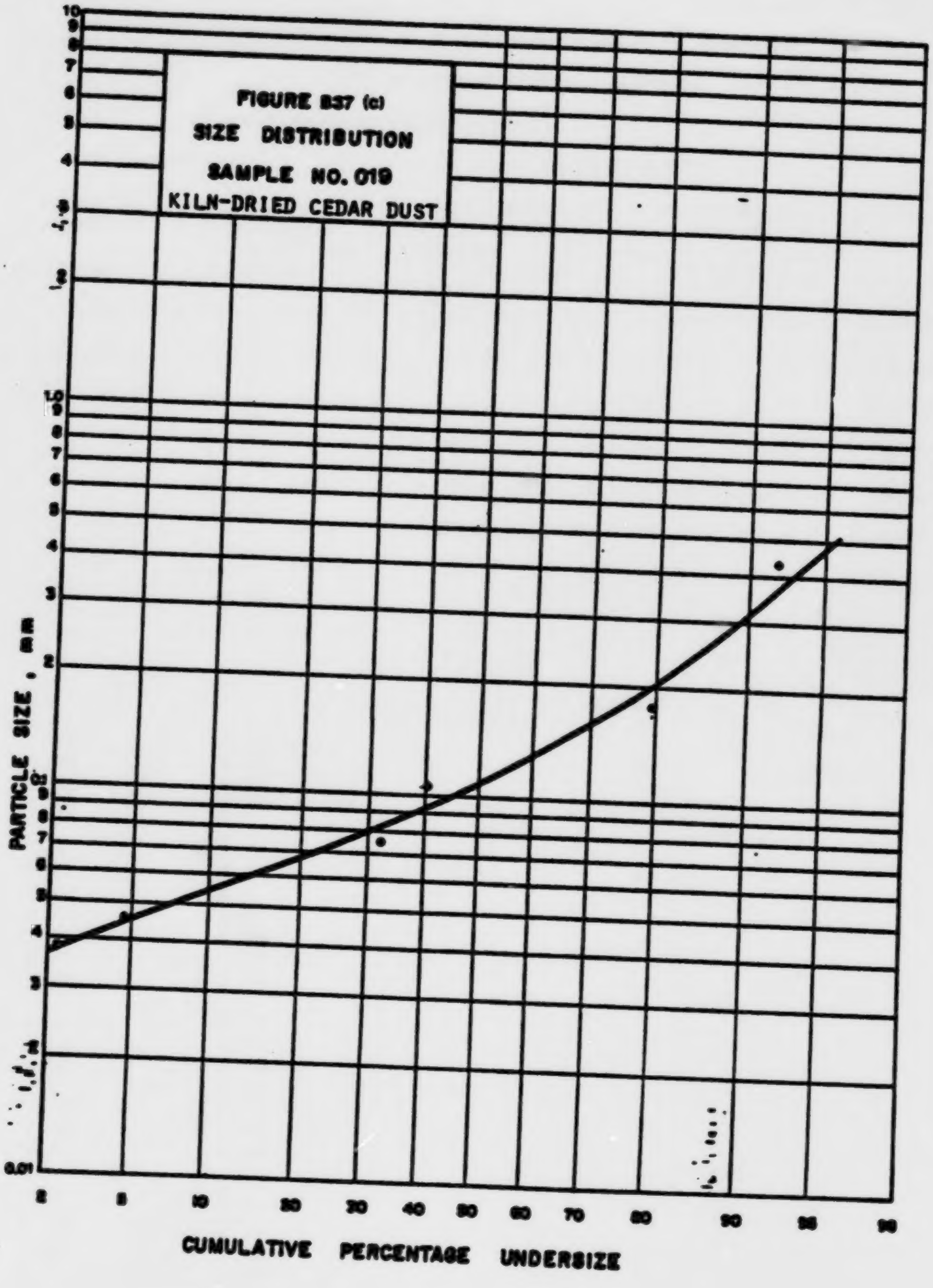

FIGURE B37 (c)
SIZE DISTRIBUTION
SAMPLE NO. 019
KILN-DRIED CEDAR DUST

TABLE B38 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEMLOCK SAWDUST (WONNOCK LUMBER) SAMPLE # 026

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	17.6		
		1.5	5.2
		2.9	7.5
		4.3	7.8
		6.2	8.4
		11.8	16.3
		13.2	17.5
		14.6	17.6
24.3	25.9		
		1.5	5.2
		2.9	6.7
		4.3	9.3
		9.0	13.8
		14.6	20.7
		21.0	22.0
		24.3	25.9
45.0	52.1		
		1.5	4.2
		2.9	10.6
		4.3	14.1
		9.0	19.1
		18.2	29.7
		33.9	28.9
		45.0	52.1
60.3	65.7		
		1.5	9.8
		2.9	13.3
		4.3	14.5
		9.0	21.0
		24.3	42.9
		45.0	49.2
		60.3	65.7
85.6	94.9		
		1.5	26.3
		4.3	27.3
		24.3	62.2
		45.0	75.1
		60.3	82.2
		70.4	84.9
		85.6	94.9
115.9	118.6		
		1.5	6.8
		4.3	15.3
		24.3	41.2
		45.0	93.8
		70.4	103.6
		85.6	112.4
		115.9	118.6

TABLE B38 (b)

HEMLOCK SAWDUST (WONNOCK LUMBER) SAMPLE # 026 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	17.6	38.1	20.9	1.83	58.4	52.56	2.88	.81
24.3	25.9	56.0	24.9	2.25	52.9	52.57	3.44	.97
45.0	52.1	101.0	42.9	2.36	51.7	52.57	5.92	1.67
60.3	65.7	140.7	64.0	2.20	53.4	52.57	8.84	2.49
85.6	94.9	223.7	122.5	1.83	58.4	52.57	16.91	4.77
115.9	118.6	280.6	136.2	2.06	55.1	52.57	18.81	5.30

SHEAR INDEX (N) = 1.64

YIELD LOCUS	PERCENT FIT
1	98.9
2	99.4
3	95.8
4	99.2
5	98.9
6	97.1

TABLE B38 (c)

WALL FRICTION TEST RESULTS

HEMLOCK SAW DUST (WONNOCK LUMBER) SAMPLE 026

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	62.8
150.2	53.7
122.2	44.6
94.1	36.2
66.0	25.9
52.0	20.1
38.0	16.6
23.9	11.2
9.9	6.0
4.7	4.2

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	98.2
150.2	84.9
122.2	69.5
94.1	53.7
66.0	38.6
52.0	32.6
38.0	24.6
23.9	16.8
9.9	5.5
4.7	2.1

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	33.0
150.2	28.1
122.2	25.3
94.1	21.8
66.0	16.1
52.0	14.0
38.0	11.1
23.9	7.7
9.9	4.0
4.7	2.7

TABLE B38 (c) con't

WALL FRICTION TEST RESULTS

HEMLOCK SAW DUST (WONNOCK LUMBER) SAMPLE 026 (CONT.)

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	101.0
150.2	90.1
122.2	77.2
94.1	62.4
66.0	43.8
52.0	35.1
38.0	25.3
23.9	14.7
9.9	7.0
4.7	3.5

TABLE B38 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

HEMLOCK SAWDUST SAMPLE # 026

                                     - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT      <---------------FLOW PROPERTIES----------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC      UNCONFIN  EFFECT  INTERNAL  COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N       YIELD     FRIC    FRIC ANG
                                 STRESS        STRESS    ANGLE   AT FREE
                                INST   TIME                       SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM       G/SQ CM    DEG      DEG    G/SQ CM


CONSOLIDATION PERIOD  20 HOURS

  24.3    28.1    24.3    30.6   56.0   67.2    39.8     60.7     52.6      5.50
 115.9   115.2   115.9   126.0  280.6  279.0   134.2     54.8     52.6     18.53
 115.9   113.2   115.9   118.6  280.6  264.7   116.1     52.5     52.6     16.02

CONSOLIDATION PERIOD  74 HOURS

  60.3    53.9    60.3    66.2  140.7  146.5    71.5     55.2     52.6      9.87

CONSOLIDATION PERIOD  94 HOURS

  24.3    17.2    24.3    23.0   56.0   52.1    20.1     49.5     52.6      2.78
  60.3    63.0    60.3    70.5  140.7  155.1    82.9     57.7     52.6     11.45
  85.6    88.2    85.6   100.9  223.7  222.0   120.2     58.0     52.6     16.59


                        SHEAR INDEX (N)    =    1.64

                        COHESION/ TENSILE
                              STRENGTH =    3.55
```

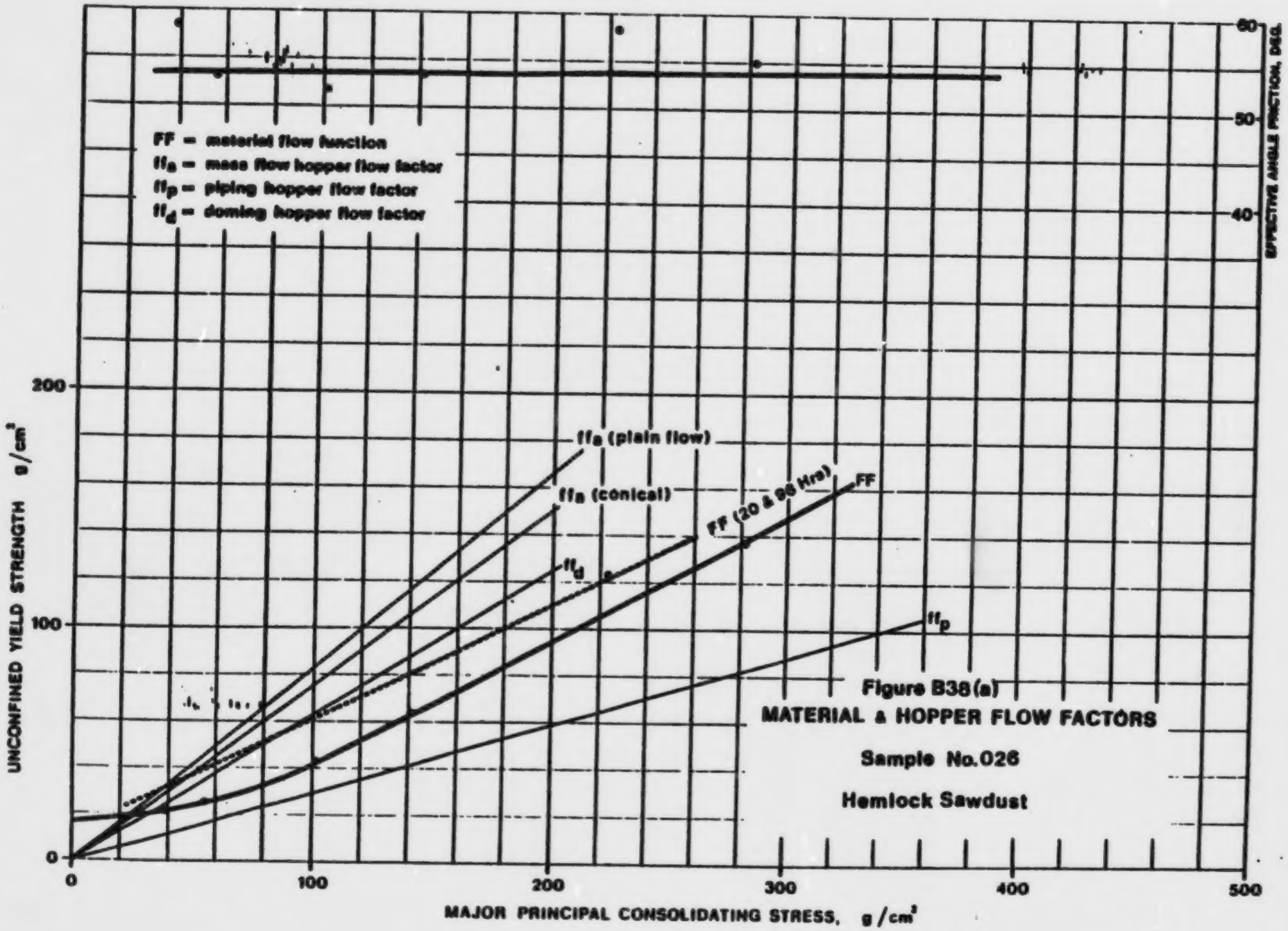

Figure B38(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No.026
Hemlock Sawdust

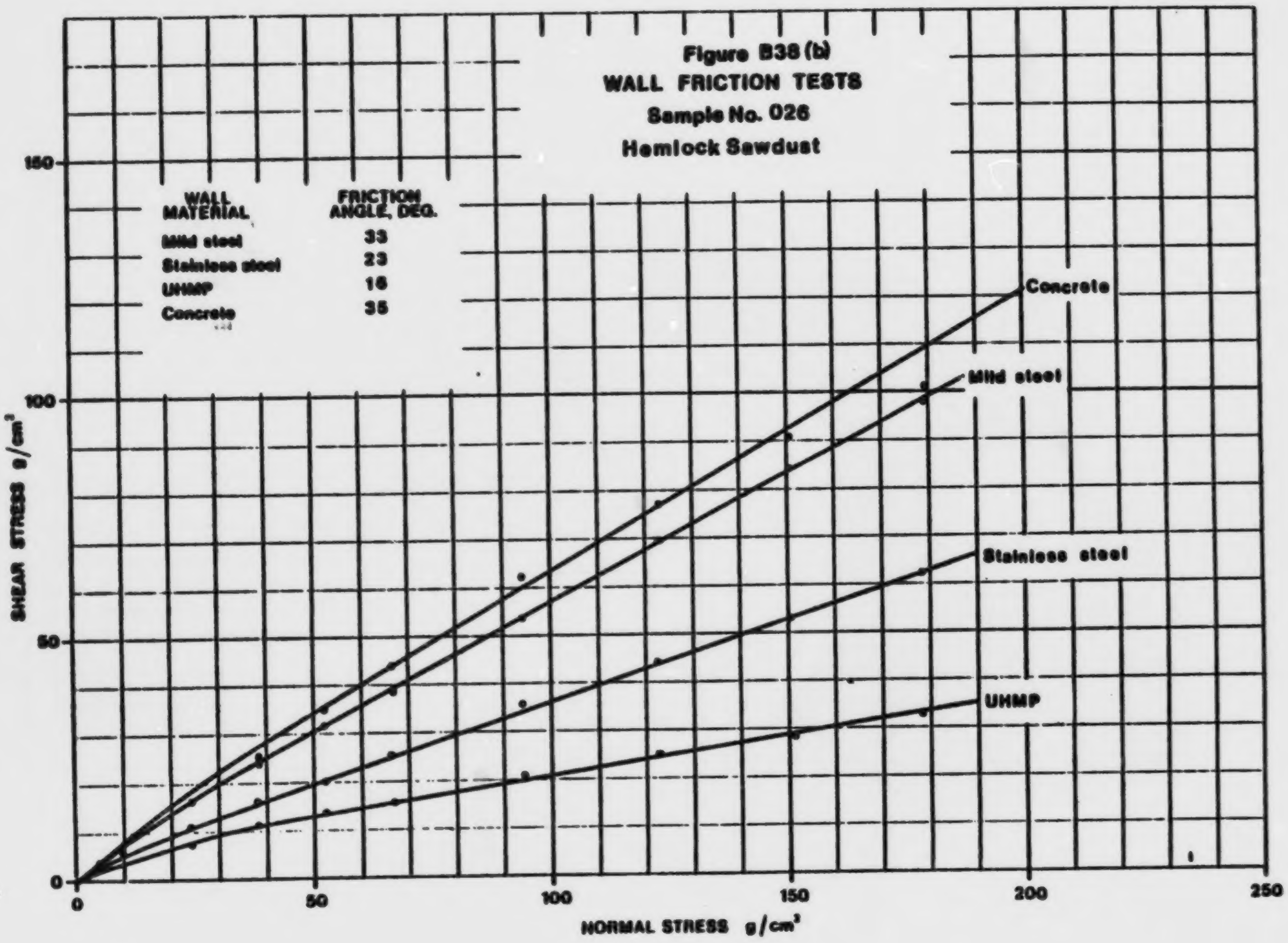

Figure B38 (b)
WALL FRICTION TESTS
Sample No. 026
Hemlock Sawdust

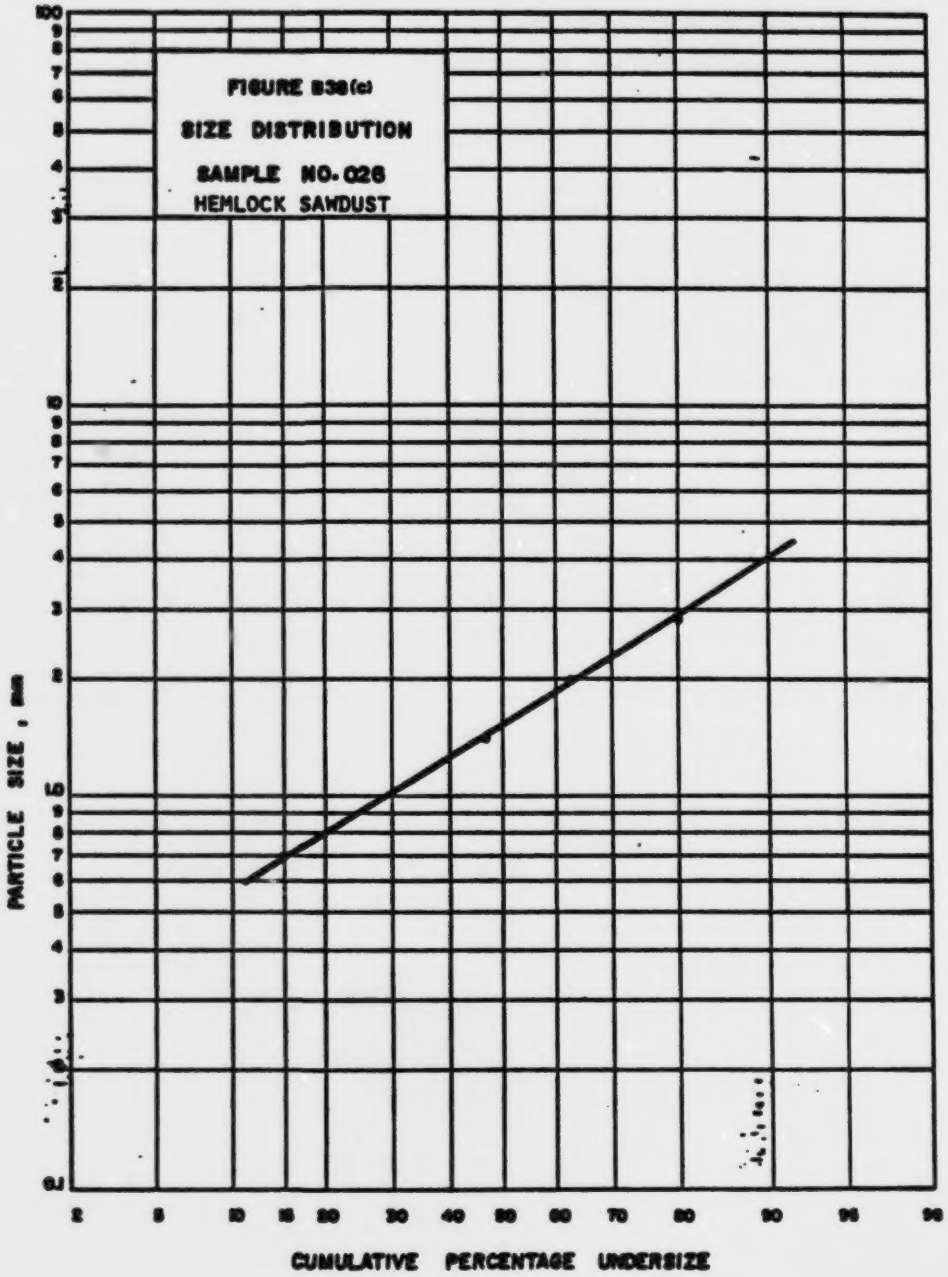

FIGURE B38(c)
SIZE DISTRIBUTION
SAMPLE NO. 026
HEMLOCK SAWDUST

TABLE B39 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

HEM-FIR SAWDUST (WEYERHAUSER KAMLOOPS) SAMPLE # 028

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	17.2		
		1.5	3.3
		2.9	6.0
		4.3	8.1
		6.2	8.5
		11.8	13.1
		13.2	16.1
		14.6	17.2
24.3	27.0		
		1.5	6.5
		2.9	7.4
		4.3	9.5
		9.0	15.8
		14.6	19.9
		21.0	25.4
		24.3	27.0
45.0	50.7		
		1.5	6.0
		2.9	8.7
		4.3	14.2
		9.0	18.0
		18.2	30.0
		33.9	41.7
		45.0	50.7
60.3	61.1		
		1.5	5.7
		2.9	11.8
		4.3	18.5
		9.0	28.2
		24.3	47.6
		45.0	52.9
		60.3	61.1
85.6	79.6		
		1.5	5.7
		4.3	11.5
		9.0	18.0
		45.0	55.6
		60.3	66.0
		70.4	78.0
		85.6	79.6
115.9	98.2		
		1.5	10.1
		4.3	21.3
		9.0	34.9
		24.3	56.7
		60.3	85.6
		85.6	88.4
		115.9	98.2

TABLE B39 (b)

HEM-FIR SAWDUST (WEYERHAUSER KAMLOOPS) SAMPLE # 028 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	17.2	35.4	16.5	2.15	54.5	52.40	2.33	.71
24.3	27.0	60.0	28.6	2.09	55.2	52.40	4.05	1.23
45.0	50.7	108.4	49.7	2.18	54.2	52.40	7.03	2.13
60.3	61.1	145.2	66.5	2.18	54.2	52.40	9.41	2.85
85.6	79.6	183.6	67.1	2.74	49.0	52.40	9.49	2.88
115.9	98.2	250.1	92.5	2.70	49.3	52.40	13.09	3.97

SHEAR INDEX (N) = 1.60

YIELD LOCUS	PERCENT FIT
1	98.9
2	99.8
3	99.3
4	97.7
5	99.1
6	97.8

TABLE B39 (c)

WALL FRICTION TEST RESULTS

HEM-FIR SAW DUST (WEYERHAEUSER KAMLOOPS) SAMPLE 028

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	104.5
150.2	89.1
122.1	73.7
94.0	58.2
66.0	42.1
51.9	33.7
37.9	25.3
23.9	16.1
9.8	7.0
4.6	3.5

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	78.6
150.2	66.7
122.1	55.4
94.0	44.2
66.0	31.6
51.9	26.0
37.9	19.6
23.9	13.3
9.8	6.3
4.6	3.5

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	40.7
150.2	34.4
122.1	28.8
94.0	22.5
66.0	16.1
51.9	13.3
37.9	9.8
23.9	6.3
9.8	3.5
4.6	1.4

TABLE B39 (c) con't

WALL FRICTION TEST RESULTS

HEM-FIR SAWDUST (WEYERHAEUSER KAMLOOPS) SAMPLE 028 (CONT.)

WALL MATERIAL - RUSTY MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	114.4
150.2	98.9
122.1	81.4
94.0	63.9
66.0	45.6
51.9	36.5
37.9	26.7
23.9	16.8
9.8	7.7
4.6	4.2

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.2	127.0
150.2	108.8
122.1	87.0
94.0	68.1
66.0	47.7
51.9	37.2
37.9	26.0
23.9	16.8
9.8	7.7
4.6	4.2

TABLE B39 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

HEM-FIR SAWDUST (WEYERHAEUSER KAMLOOPS) SAMPLE 028

                         - TIME CONSOLIDATION RESULTS

CONSOLIDATION   YIELD POINT    <---------------FLOW PROPERTIES-------------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC      UNCONFIN  EFFECT  INTERNAL  COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N       YIELD     FRIC    FRIC ANG
                                 STRESS        STRESS    ANGLE   AT FREE
                                INST   TIME                       SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM       G/SQ CM    DEG      DEG     G/SQ CM

CONSOLIDATION PERIOD  20 HOURS

  24.3   22.9     2.9     9.5   60.0   56.4   32.4     54.8       43.8     6.03
 115.9   98.2     4.3    32.2  250.1  261.2  142.3     53.2       43.8    26.46


                   SHEAR INDEX (N)   =   1.60

                   COHESION/ TENSILE
                           STRENGTH =   2.28
```

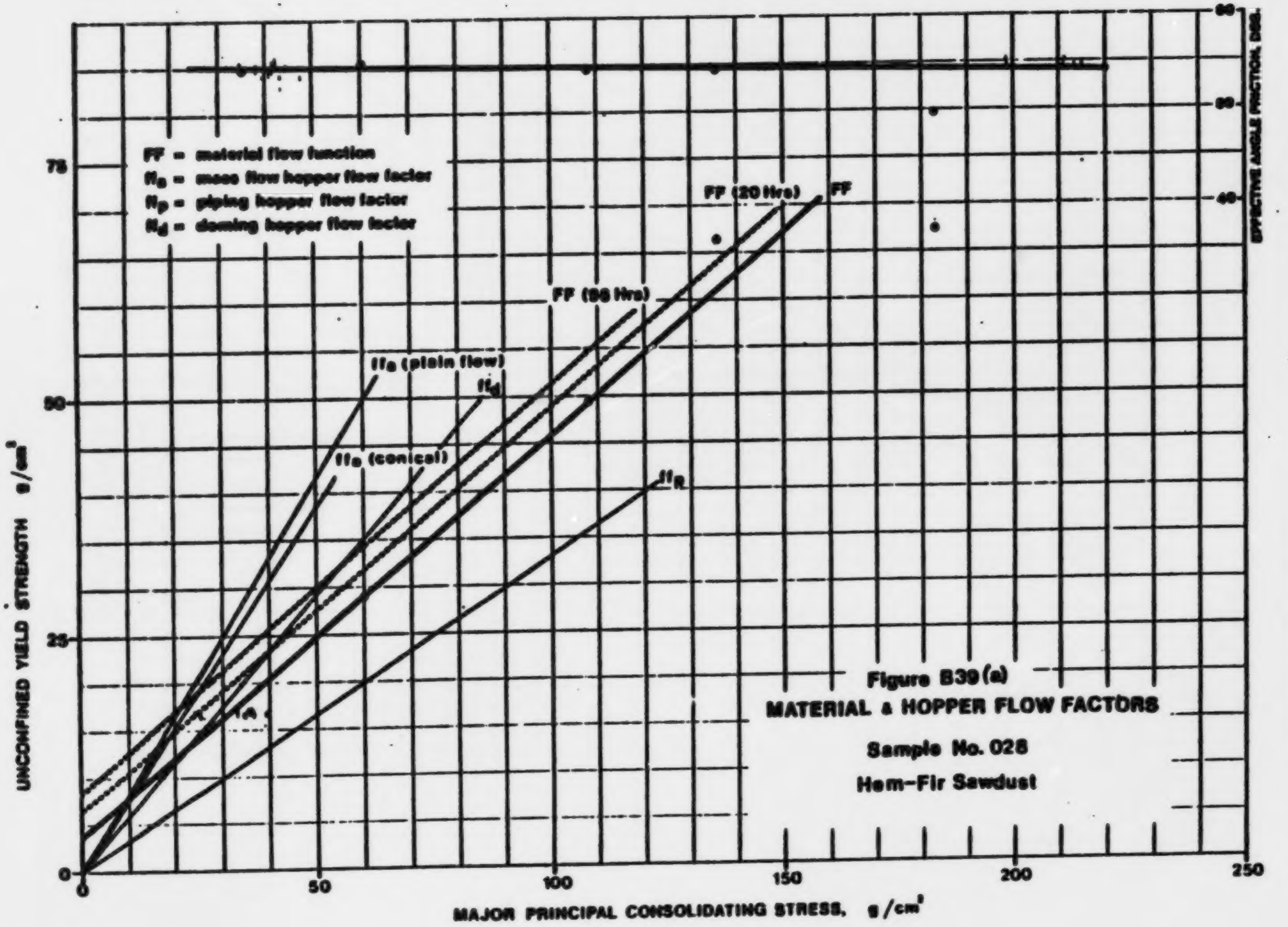

Figure B39(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 028
Hem-Fir Sawdust

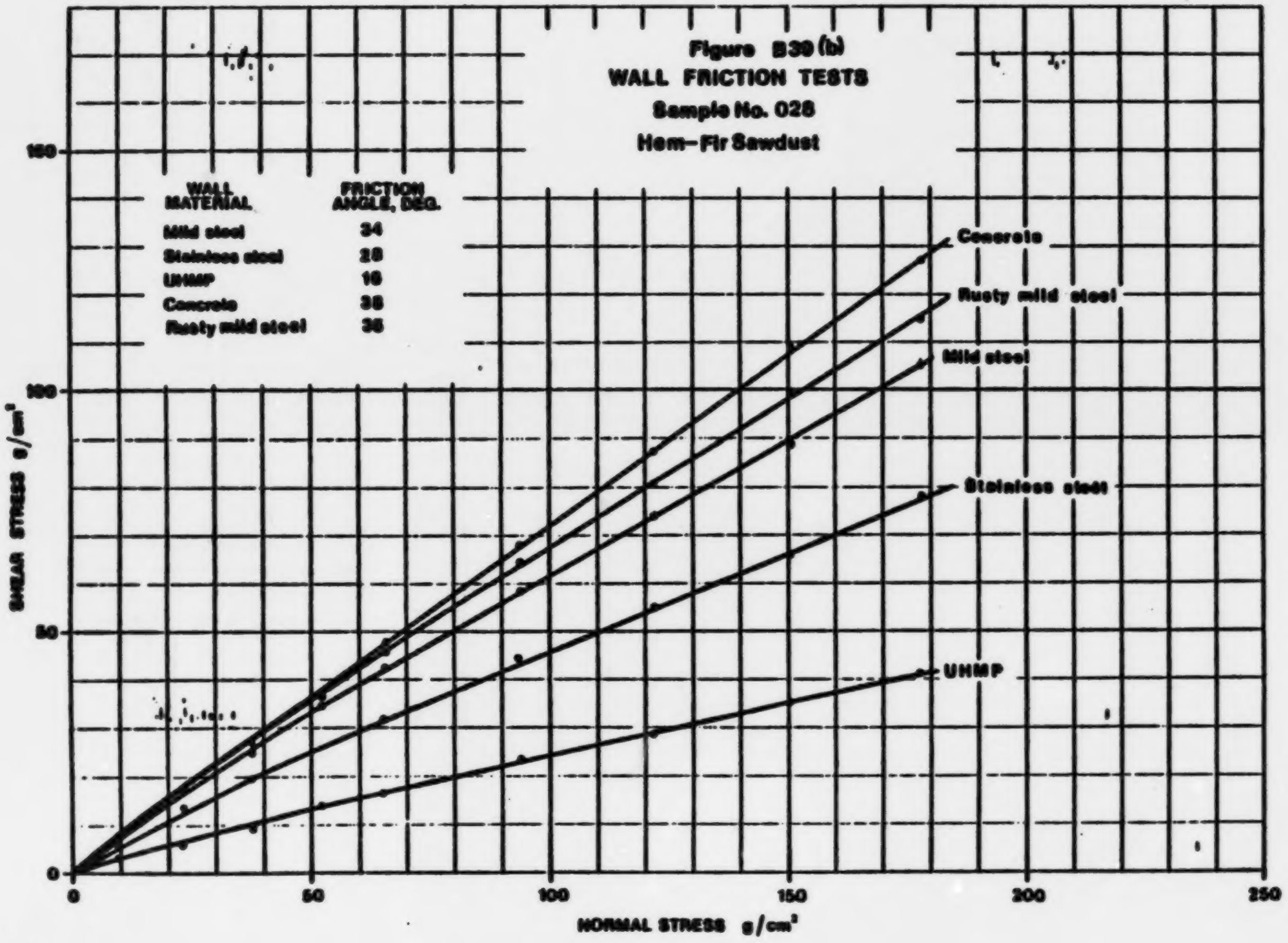

Figure B39 (b)
WALL FRICTION TESTS
Sample No. 028
Hem-Fir Sawdust

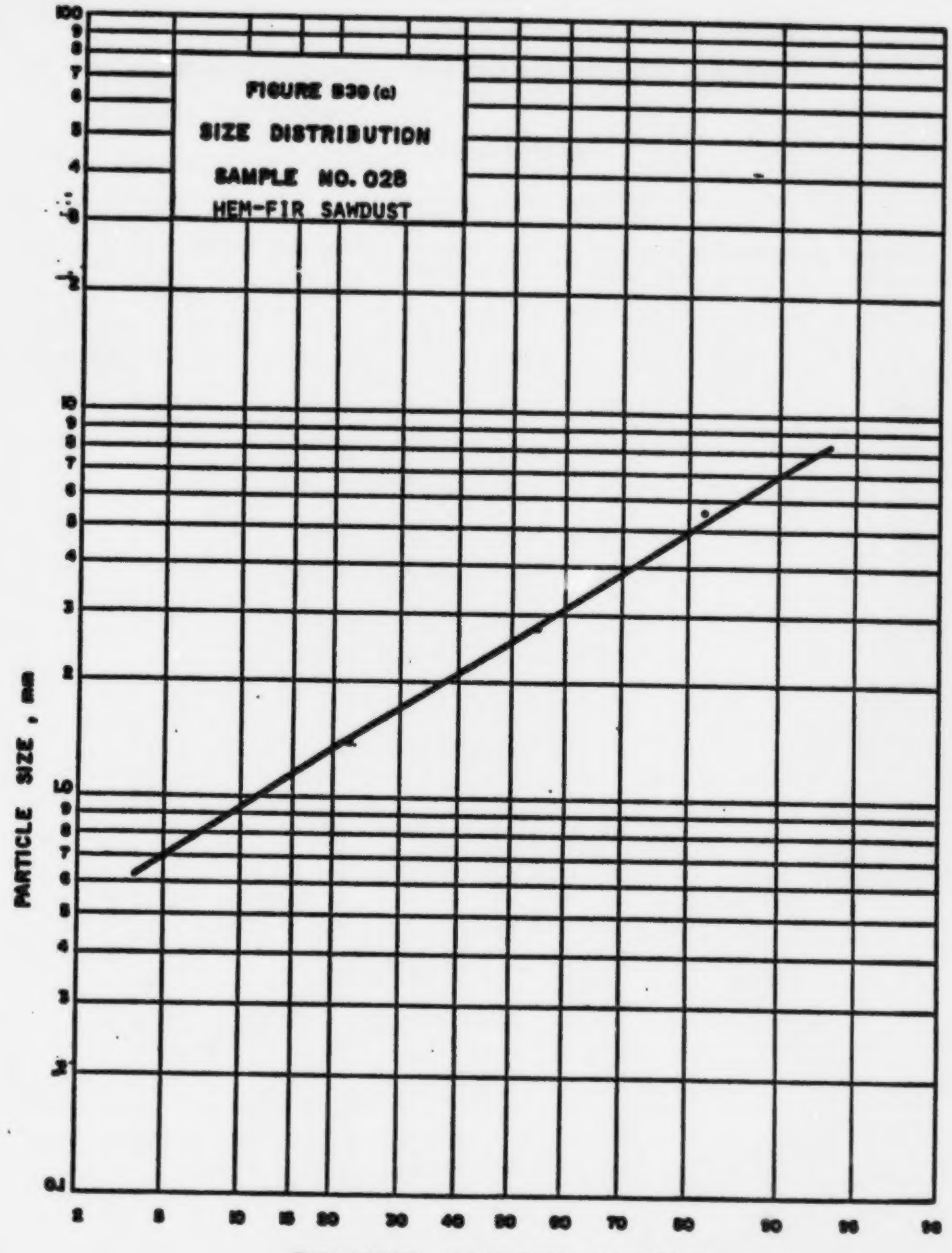

FIGURE B30 (c)

SIZE DISTRIBUTION

SAMPLE NO. 028

HEM-FIR SAWDUST

TABLE B40 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

CEDAR SAWDUST (MB-CANADIAN WHITE PINE DIV.) SAMPLE # 029

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	14.6	1.5	4.7
		2.9	6.5
		4.3	6.5
		6.2	8.1
		11.8	11.7
		13.2	13.4
		14.6	14.6
24.3	23.9	1.5	4.1
		2.9	6.0
		4.3	7.1
		9.0	13.5
		14.6	17.5
		21.0	21.8
		24.3	23.9
45.0	41.2	1.5	5.0
		2.9	7.5
		4.3	8.9
		9.0	14.3
		18.2	23.7
		33.9	36.5
		45.0	41.2
60.3	56.2	1.5	5.2
		2.9	7.5
		4.3	9.7
		9.0	17.3
		24.3	31.9
		45.0	47.5
		60.3	56.2
85.6	79.6	1.5	4.7
		4.3	9.4
		9.0	16.4
		45.0	52.9
		60.3	65.5
		70.4	70.9
		85.6	79.6
115.9	91.6	1.5	6.8
		4.3	12.7
		9.0	20.7
		24.3	38.2
		60.3	68.7
		85.6	80.7
		115.9	91.6

TABLE B40 (b)

CEDAR SAWDUST (MB-CANADIAN WHITE PINE DIV.) SAMPLE # 029 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	MAJ PRINC CONSOL'N STRESS G/SQ CM	UNCONFIN YIELD STRESS G/SQ CM	FLOW FUNC	EFFECT FRIC ANGLE DEG	INTERNAL FRIC ANG AT FREE SURFACE DEG	COHESION G/SQ CM	TENSILE STRENGTH G/SQ CM
14.6	14.6	33.2	10.6	3.14	49.5	52.82	1.56	.57
24.3	23.9	55.1	17.2	3.19	49.2	52.82	2.54	.93
45.0	41.2	97.2	27.0	3.60	47.2	52.82	3.98	1.45
60.3	56.2	130.1	36.1	3.60	47.1	52.82	5.32	1.95
85.6	79.6	184.5	51.1	3.61	47.1	52.82	7.52	2.75
115.9	91.6	231.0	51.4	4.49	43.6	52.82	7.57	2.77

SHEAR INDEX (N) = 1.47

YIELD LOCUS	PERCENT FIT
1	99.3
2	99.8
3	99.7
4	99.7
5	99.5
6	99.5

TABLE D40 (c)

WALL FRICTION TEST RESULTS

CEDAR SAWDUST (MB - CAN.WHITE PINE DIV.) SAMPLE 029

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	74.4
150.6	62.4
122.5	51.9
94.4	40.7
66.4	30.2
52.3	24.6
38.3	18.2
24.3	12.3
10.2	6.3
5.0	3.5

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	98.9
150.6	83.5
122.5	69.5
94.4	54.7
66.4	40.0
52.3	32.3
38.3	24.6
24.3	16.1
10.2	7.7
5.0	4.2

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	37.9
150.6	33.0
122.5	26.7
94.4	22.5
66.4	16.1
52.3	14.0
38.3	10.5
24.3	7.4
10.2	3.5
5.0	2.1

TABLE B40 (c) con't

WALL FRICTION TEST RESULTS

CEDAR SAWDUST (WEYERHAEUSER KAMLOOPS) SAMPLE 029 (CONT.)

WALL MATERIAL - RUSTY MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	109.5
150.6	94.0
122.5	77.2
94.4	59.6
66.4	42.1
52.3	33.7
38.3	23.9
24.3	15.4
10.2	7.7
5.0	3.5

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.6	122.1
150.6	106.0
122.5	85.6
94.4	65.3
66.4	47.7
52.3	37.9
38.3	28.8
24.3	18.9
10.2	9.1
5.0	5.6

TABLE B40 (d)

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COMPUTER ANALYSIS OF STORAGE AT REST

CEDAR SAWDUST (MB-CANADIAN WHITE PINE DIV.) SAMPLE 029

                              - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT     <---------------FLOW PROPERTIES---------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC     UNCONFIN  EFFECT   INTERNAL  COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N      YIELD     FRIC     FRIC ANG
                                  STRESS      STRESS    ANGLE    AT FREE
                                 INST   TIME                      SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM      G/SQ CM    DEG       DEG     G/SQ CM

CONSOLIDATION PERIOD  20 HOURS

 115.9   91.1   115.9    90.6  231.0  220.4   41.3      41.3      53.0      6.05
 115.9   91.6   115.9    81.8  231.0  206.1   30.4      38.1      53.0      4.45


                      SHEAR INDEX (N)   =   1.47

                      COHESION/ TENSILE
                            STRENGTH =    2.74
```

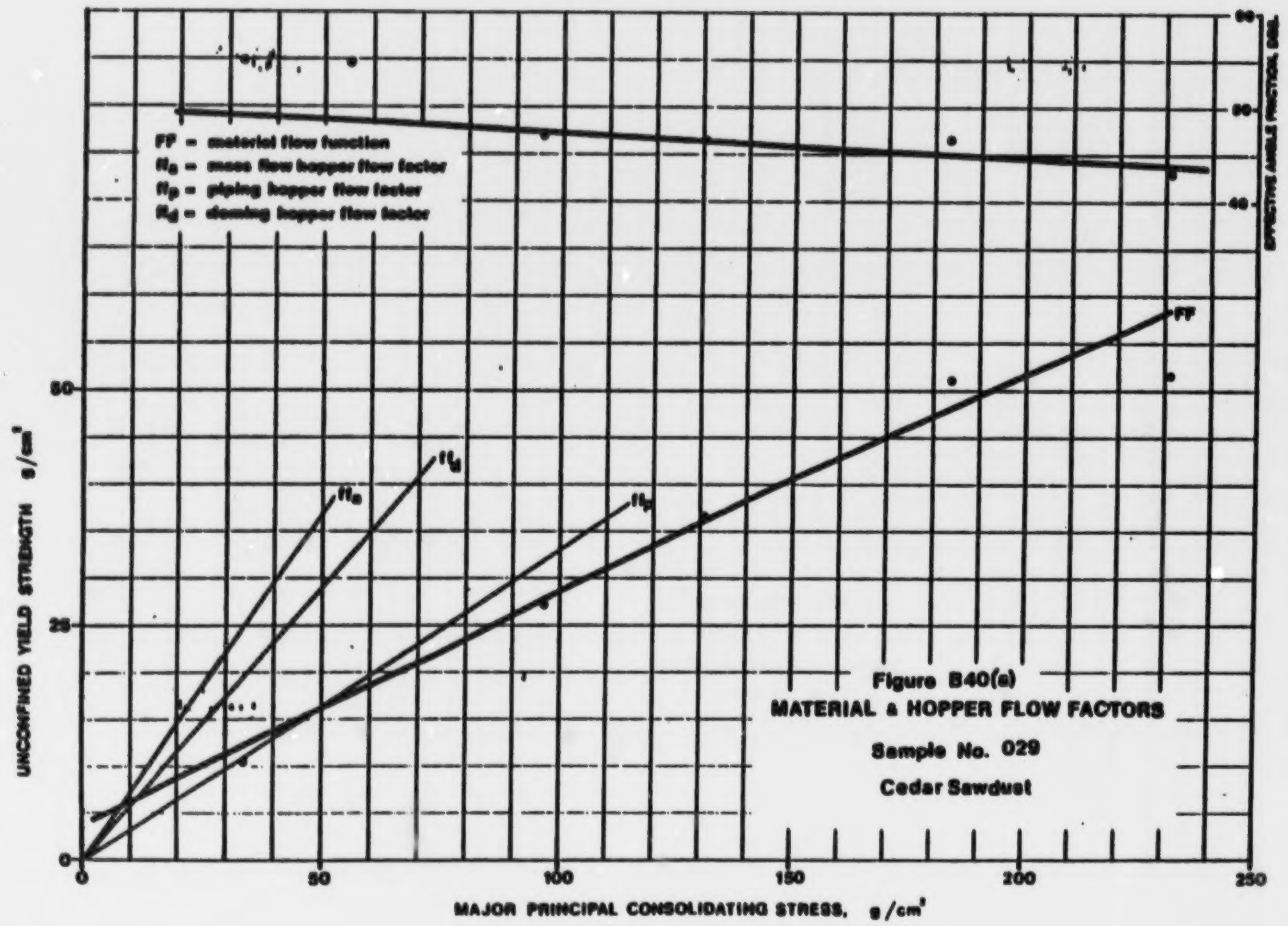

Figure B40(a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 029

Cedar Sawdust

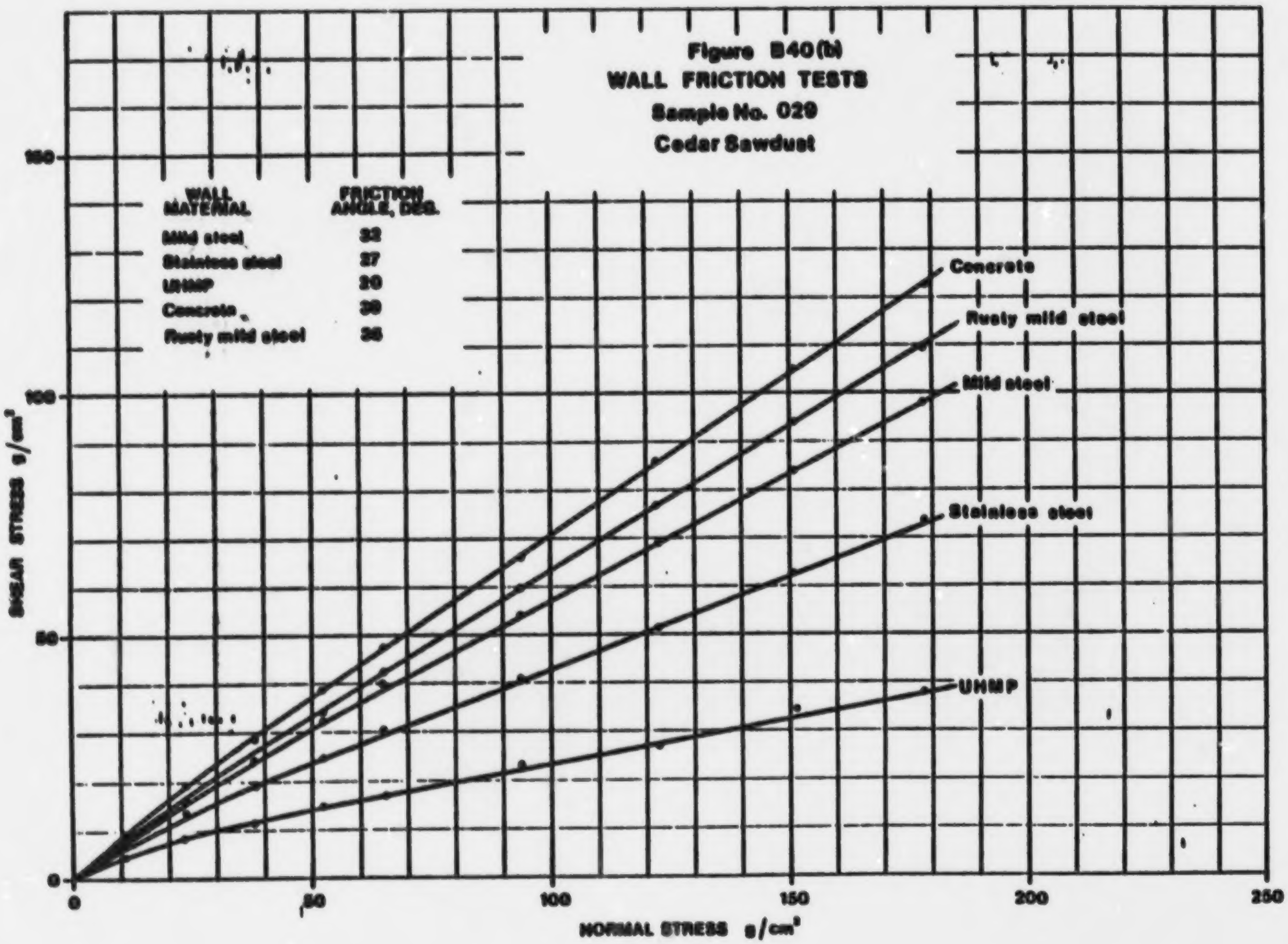
Figure B40(b)
WALL FRICTION TESTS
Sample No. 029
Cedar Sawdust
WALL MATERIAL
FRICTION ANGLE, DEG.
Mild steel 32
Stainless steel 27
UHMP 20
Concrete 39
Rusty mild steel 36
Concrete
Rusty mild steel
Mild steel
Stainless steel
UHMP
SHEAR STRESS g/cm²
0
50
100
150
NORMAL STRESS g/cm²
0
50
100
150
200
250

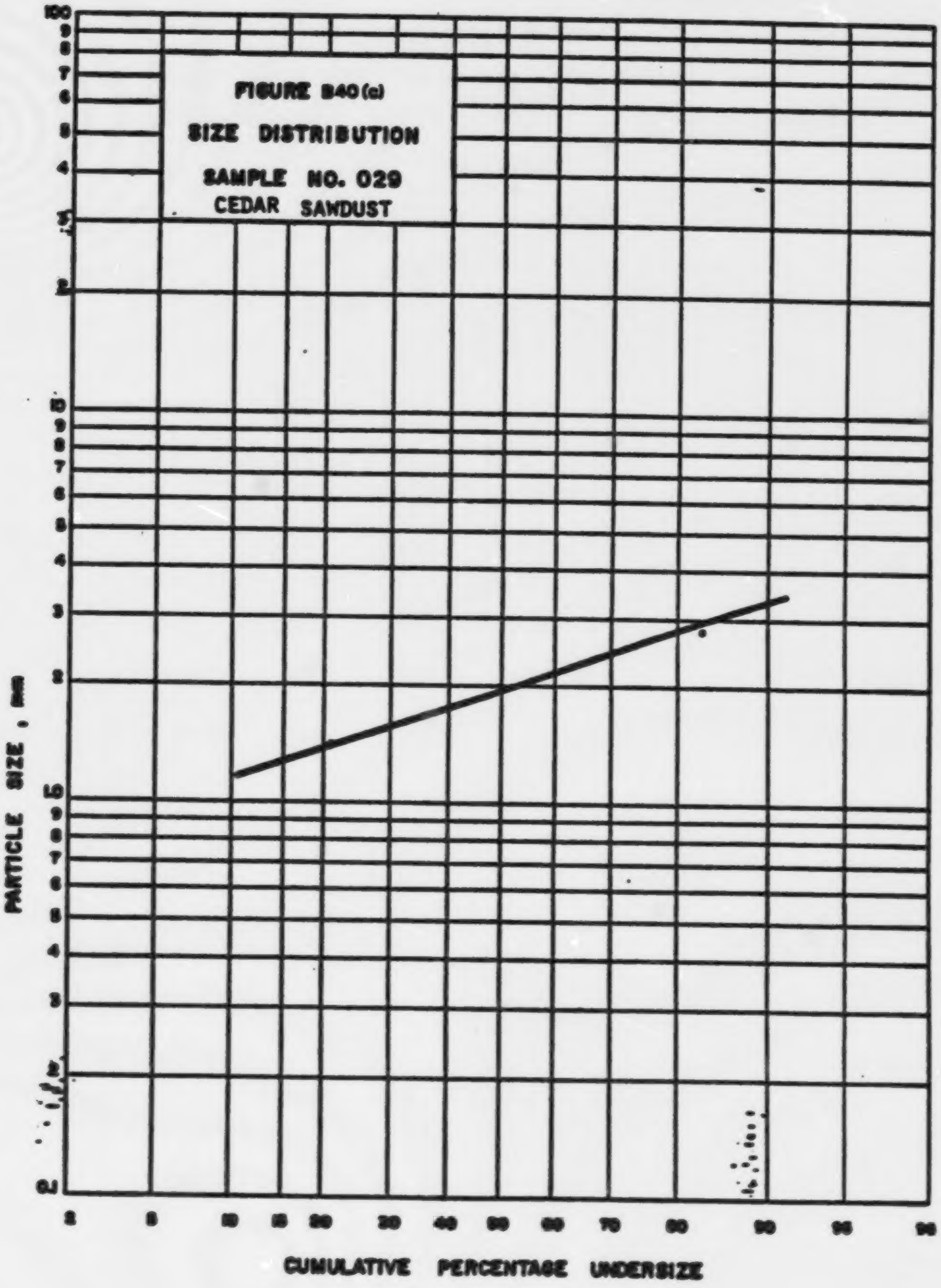

FIGURE B40(c)
SIZE DISTRIBUTION
SAMPLE NO. 029
CEDAR SAWDUST

TABLE B41 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

PEAT - MECHANICALLY DEWATERED & NOT DRIED (FISONS WESTERN PEAT) SAMPLE # 037

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	11.8		
		1.5	4.4
		2.9	5.7
		4.3	6.6
		6.2	8.3
		11.8	11.0
		13.2	12.2
		14.6	11.8
24.3	19.3		
		1.5	4.8
		2.9	6.0
		4.3	7.9
		9.0	11.2
		14.6	14.8
		21.0	18.1
		24.3	19.3
45.0	39.7		
		1.5	8.1
		2.9	9.4
		4.3	11.6
		9.0	17.3
		18.2	22.9
		33.9	32.1
		45.0	39.7
60.3	51.8		
		1.5	8.6
		2.9	10.6
		4.3	12.2
		9.0	18.1
		24.3	29.3
		45.0	43.0
		60.3	51.8
85.6	68.2		
		1.5	8.7
		4.3	10.6
		24.3	34.4
		45.0	42.9
		60.3	52.8
		70.4	64.2
		85.6	68.2
115.9	93.0		
		1.5	8.6
		4.3	12.1
		24.3	37.4
		45.0	53.7
		70.4	66.3
		85.6	77.8
		115.9	93.0

TABLE B41 (b)

PEAT - MECHANICALLY DEWATERED & NOT DRIED (FISONS WESTERN PEAT) SAMPLE # 037
CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	11.8	29.1	11.9	2.46	46.7	45.72	2.06	.80
24.3	19.3	46.1	16.4	2.81	43.8	45.72	2.85	1.10
45.0	39.7	89.4	35.9	2.49	46.4	45.72	6.23	2.40
60.3	51.8	117.0	44.4	2.63	45.2	45.72	7.71	2.98
85.6	68.2	158.9	53.6	2.96	42.7	45.72	9.31	3.60
115.9	93.0	214.6	72.0	2.98	42.6	45.72	12.50	4.83

SHEAR INDEX (N) = 1.63

YIELD LOCUS	PERCENT FIT
1	99.6
2	100.0
3	99.9
4	99.9
5	99.4
6	99.5

TABLE B41 (c)

WALL FRICTION TEST RESULTS

WET PEAT (FISONS WESTERN PEAT) SAMPLE #037

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.9	133.3
150.8	119.6
122.8	105.0
94.7	88.4
66.6	70.2
52.6	60.3
38.6	49.8
24.5	34.0
10.5	17.2
5.3	10.4

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.9	132.6
150.8	116.6
122.8	101.0
94.7	83.5
66.6	66.7
52.6	57.2
38.6	47.0
24.5	36.3
10.5	12.3
5.3	5.1

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.9	129.2
150.8	107.8
122.8	86.3
94.7	67.4
66.6	45.0
52.6	34.7
38.6	24.6
24.5	14.4
10.5	6.1
5.3	2.8

TABLE B41 (c) con't

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.9	112.0
150.8	99.6
122.8	86.3
94.7	73.0
66.6	58.4
52.6	50.0
38.6	42.1
24.5	32.7
10.5	15.7
5.3	9.4

WALL MATERIAL - GLASS

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.9	72.1
150.8	63.9
122.8	54.7
94.7	46.0
66.6	37.0
52.6	32.5
38.6	27.3
24.5	22.4
10.5	14.7
5.3	11.8

TABLE B41 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

PEAT-DEWATERED & NOT DRIED SAMPLE # 037

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<----FLOW PROPERTIES--->					
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS INST	TIME	UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 20 HOURS									
24.3	19.6	24.3	19.2	46.1	45.5	15.7	43.1	45.7	2.73
45.0	36.3	45.0	44.8	89.4	99.5	50.5	52.1	45.7	8.77
60.3	46.6	60.3	58.3	117.0	130.1	62.9	50.9	45.7	10.94
85.6	73.5	85.6	82.9	158.9	185.1	89.9	51.0	45.7	15.62
115.9	87.1	115.9	98.2	214.6	227.0	88.6	45.7	45.7	15.40
CONSOLIDATION PERIOD 71 HOURS									
14.6	12.5	14.6	15.1	29.1	33.3	17.9	53.8	45.7	3.12
CONSOLIDATION PERIOD 119 HOURS									
45.0	36.1	45.0	48.1	89.4	105.4	59.4	55.1	45.7	10.32

SHEAR INDEX (N) = 1.63

COHESION/ TENSILE STRENGTH = 2.59

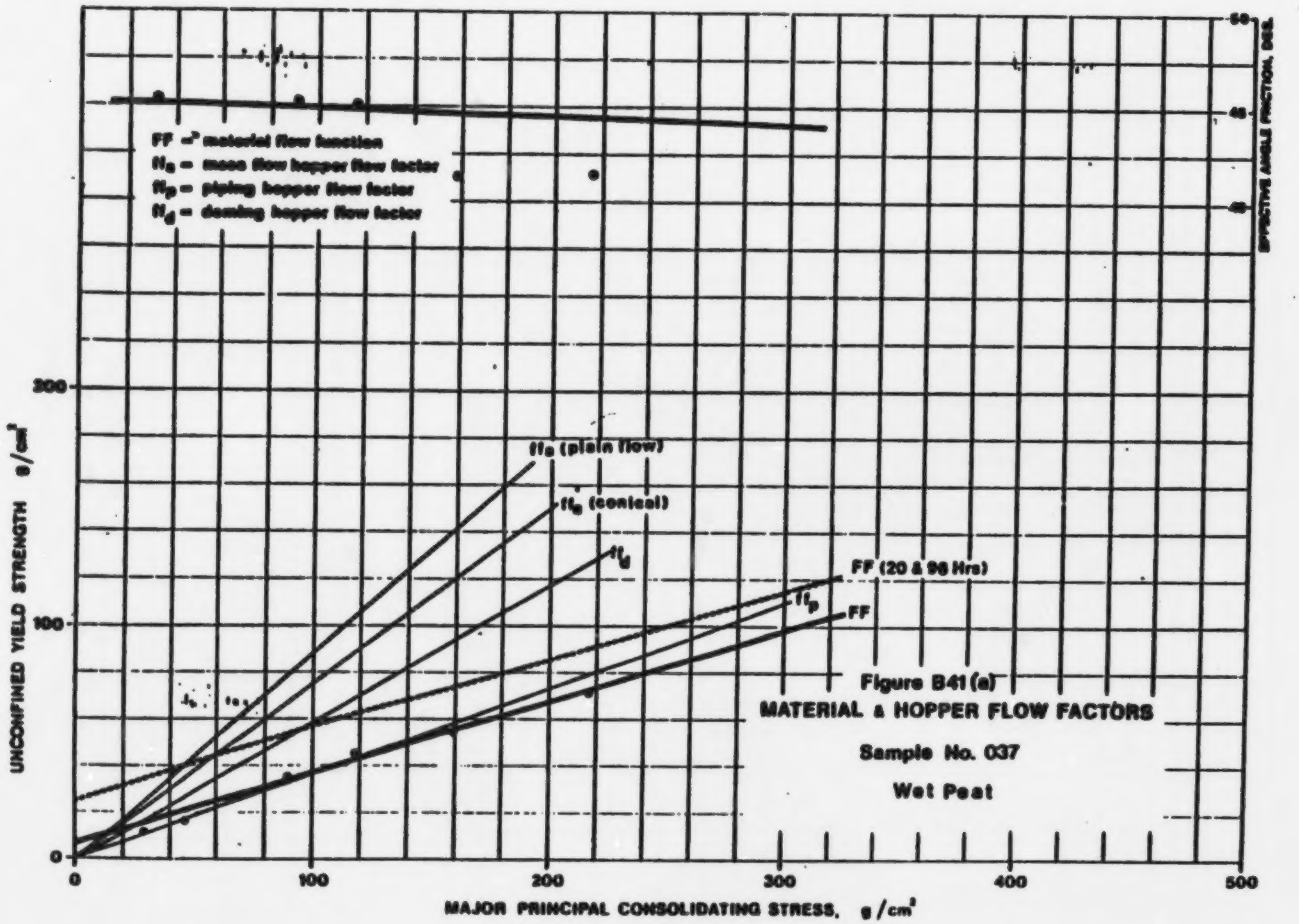

Figure B41(a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 037
Wet Peat

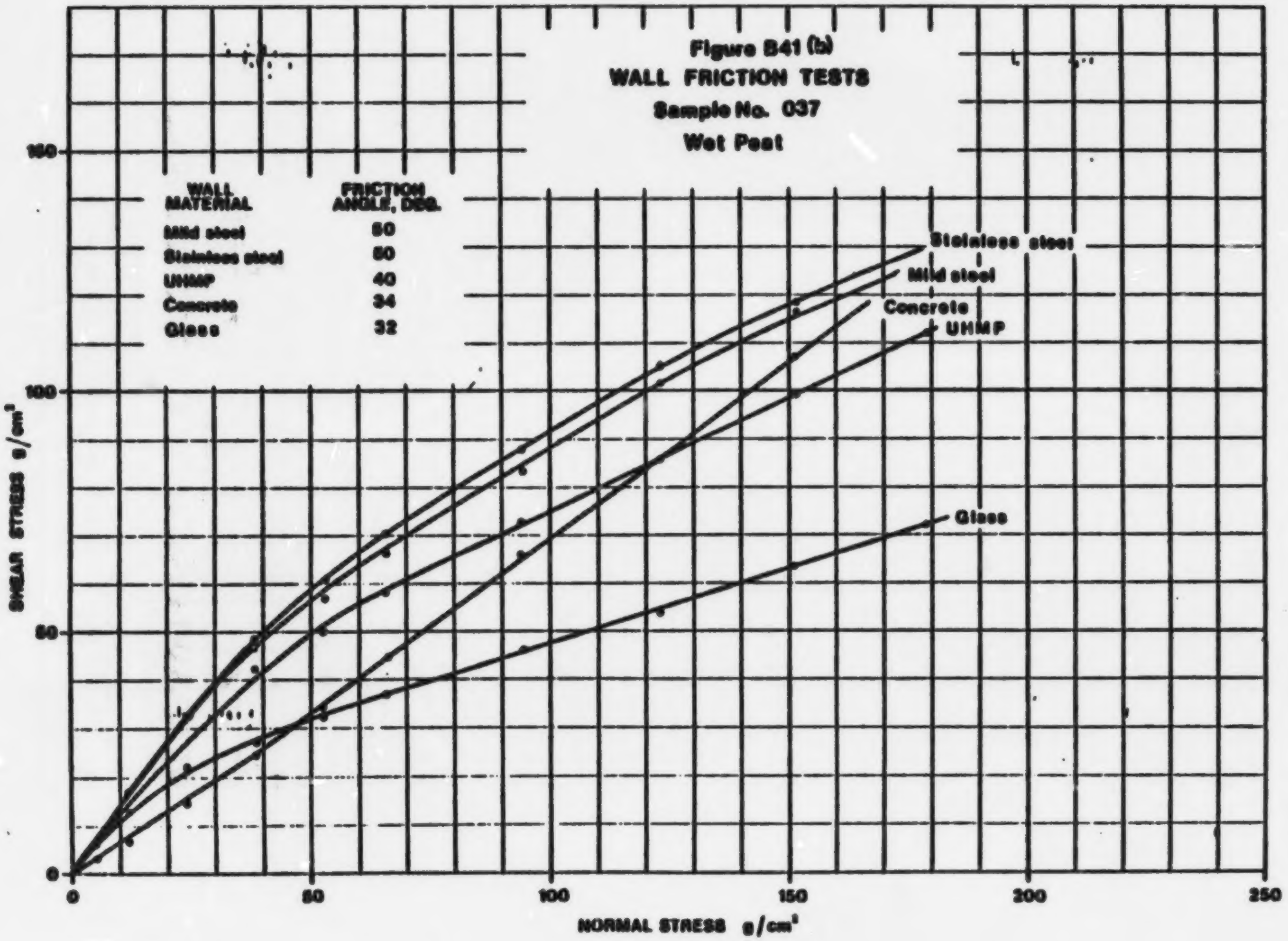

Figure B41 (b)
WALL FRICTION TESTS
Sample No. 037
Wet Peat

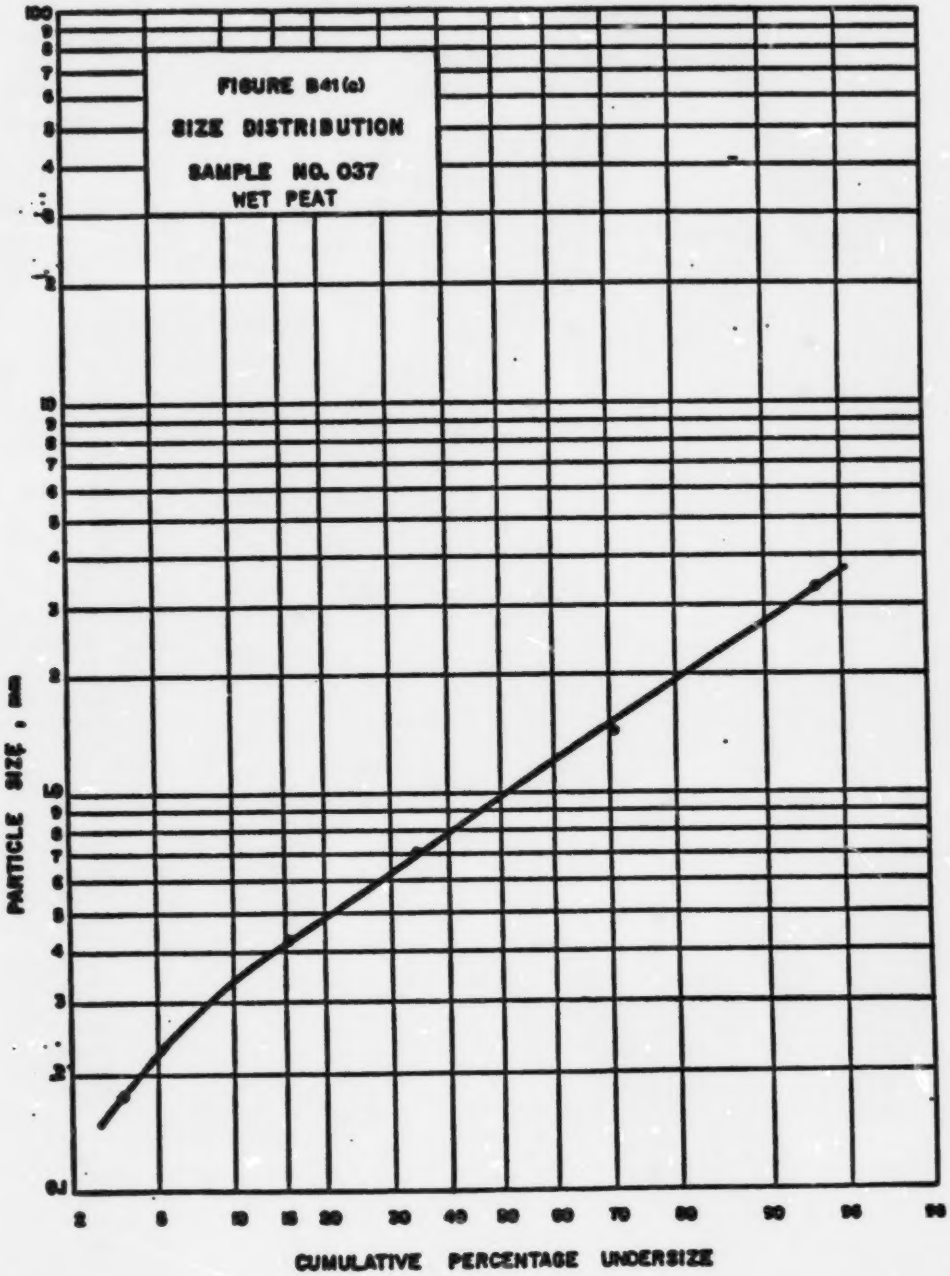
FIGURE B41(c)
SIZE DISTRIBUTION
SAMPLE NO. 037
WET PEAT

TABLE B42 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

.PEAT-DEWATERED & DRIED (FISON'S WESTERN PEAT) SAMPLE # 038

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	11.6		
		1.5	2.8
		2.9	4.1
		4.3	5.3
		6.2	6.7
		11.8	10.0
		13.2	10.7
		14.6	11.6
24.3	21.1		
		1.5	3.3
		2.9	5.4
		4.3	6.9
		9.0	12.0
		14.6	16.2
		21.0	19.9
		24.3	21.1
45.0	36.4		
		1.5	4.4
		2.9	6.9
		4.3	7.7
		9.0	12.1
		18.2	19.6
		33.9	29.1
		45.0	36.4
60.3	50.9		
		1.5	4.7
		2.9	6.9
		4.3	8.5
		9.0	14.0
		24.3	30.2
		45.0	44.2
		60.3	50.9
85.6	71.2		
		1.5	6.5
		4.3	9.1
		24.3	32.2
		45.0	48.0
		60.3	56.7
		70.4	63.4
		85.6	71.2
115.9	103.6		
		1.5	5.1
		4.3	7.7
		24.3	33.5
		45.0	54.8
		70.4	72.0
		85.6	81.0
		115.9	103.6

TABLE B42 (b)

.PEAT-DEWATERED & DRIED (FISON'S WESTERN PEAT) SAMPLE # 038 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	MAJ PRINC CONSOL'N STRESS G/SQ CM	UNCONFIN YIELD STRESS G/SQ CM	FLOW FUNC	EFFECT FRIC ANGLE DEG	INTERNAL FRIC ANG AT FREE SURFACE DEG	COHESION G/SQ CM	TENSILE STRENGTH G/SQ CM
14.6	11.6	28.5	5.1	5.57	41.8	51.47	.80	.34
24.3	21.1	51.8	12.3	4.20	45.6	51.47	1.94	.83
45.0	36.4	88.0	15.8	5.56	41.8	51.47	2.49	1.06
60.3	50.9	124.2	26.6	4.67	44.1	51.47	4.18	1.79
85.6	71.2	173.5	35.3	4.91	43.4	51.47	5.56	2.37
115.9	103.6	239.8	52.2	4.59	44.3	51.47	8.20	3.51

SHEAR INDEX (N) = 1.41

YIELD LOCUS	PERCENT FIT
1	99.9
2	99.8
3	100.0
4	99.7
5	99.9
6	99.6

TABLE B42 (c)

WALL FRICTION TEST RESULTS

PEAT - DEWATEED & DRIED (FISONS WESTERN PEAT) SAMPLE #038

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	129.8
150.2	114.4
122.1	98.2
94.1	80.7
66.0	61.0
52.0	49.8
37.9	38.6
23.9	26.0
9.9	11.9
4.6	5.6

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	117.2
150.2	102.4
122.1	85.6
94.1	67.4
66.0	49.1
52.0	40.0
37.9	30.2
23.9	20.3
9.9	7.1
4.6	3.4

WALL MATERIAL - UHMP (1)

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	92.2
150.2	78.6
122.1	66.7
94.1	54.0
66.0	40.1
52.0	34.0
37.9	26.7
23.9	17.9
9.9	8.6
4.6	4.4

TABLE B42 (c) con't

WALL MATERIAL - UHMW (2)

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	99.6
150.2	89.1
122.1	75.8
94.1	61.7
66.0	46.3
52.0	38.6
37.9	28.8
23.9	18.9
9.9	10.5
4.6	4.9

WALL MATERIAL - GLASS

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	113.0
150.2	103.1
122.1	91.2
94.1	75.8
66.0	59.6
52.0	49.1
37.9	39.3
23.9	26.7
9.9	11.9
4.6	5.6

TABLE B42 (d)

```
COMPUTER ANALYSIS OF STORAGE AT REST

PEAT-DENATURED & DRIED SAMPLE # 038

                              - TIME CONSOLIDATION RESULTS

CONSOLIDATION    YIELD POINT      <---------------FLOW PROPERTIES----------------->

NORMAL  SHEAR   NORMAL  SHEAR   MAJ PRINC      UNCONFIN  EFFECT  INTERNAL COHESION
STRESS  STRESS  STRESS  STRESS  CONSOL'N       YIELD     FRIC    FRIC ANG
                                 STRESS        STRESS    ANGLE   AT FREE
                                INST   TIME                       SURFACE

G/SQ CM G/SQ CM G/SQ CM G/SQ CM  G/SQ CM       G/SQ CM    DEG      DEG    G/SQ CM


CONSOLIDATION PERIOD  20 HOURS

  14.6   11.6    14.6    13.1   28.5   31.1    7.3      45.7      51.4      1.18
 115.9   89.1   115.9   110.7  239.8  239.4   71.8      47.7      51.4     11.29
 115.9   87.8   115.9   118.6  239.8  275.1   88.9      50.2      51.4     13.99
 115.9   93.3   115.9   115.1  239.8  268.0   80.9      49.1      51.4     12.74

CONSOLIDATION PERIOD  95 HOURS

  60.3   49.9    60.3    58.7  124.2  137.1   39.5      48.4      51.4      6.22

CONSOLIDATION PERIOD  166 HOURS

  85.6   70.6    85.6    90.6  173.5  209.2   72.5      51.4      51.4     11.41


                    SHEAR INDEX (N)   =   1.41

                    COHESION/ TENSILE
                             STRENGTH =   2.34
```

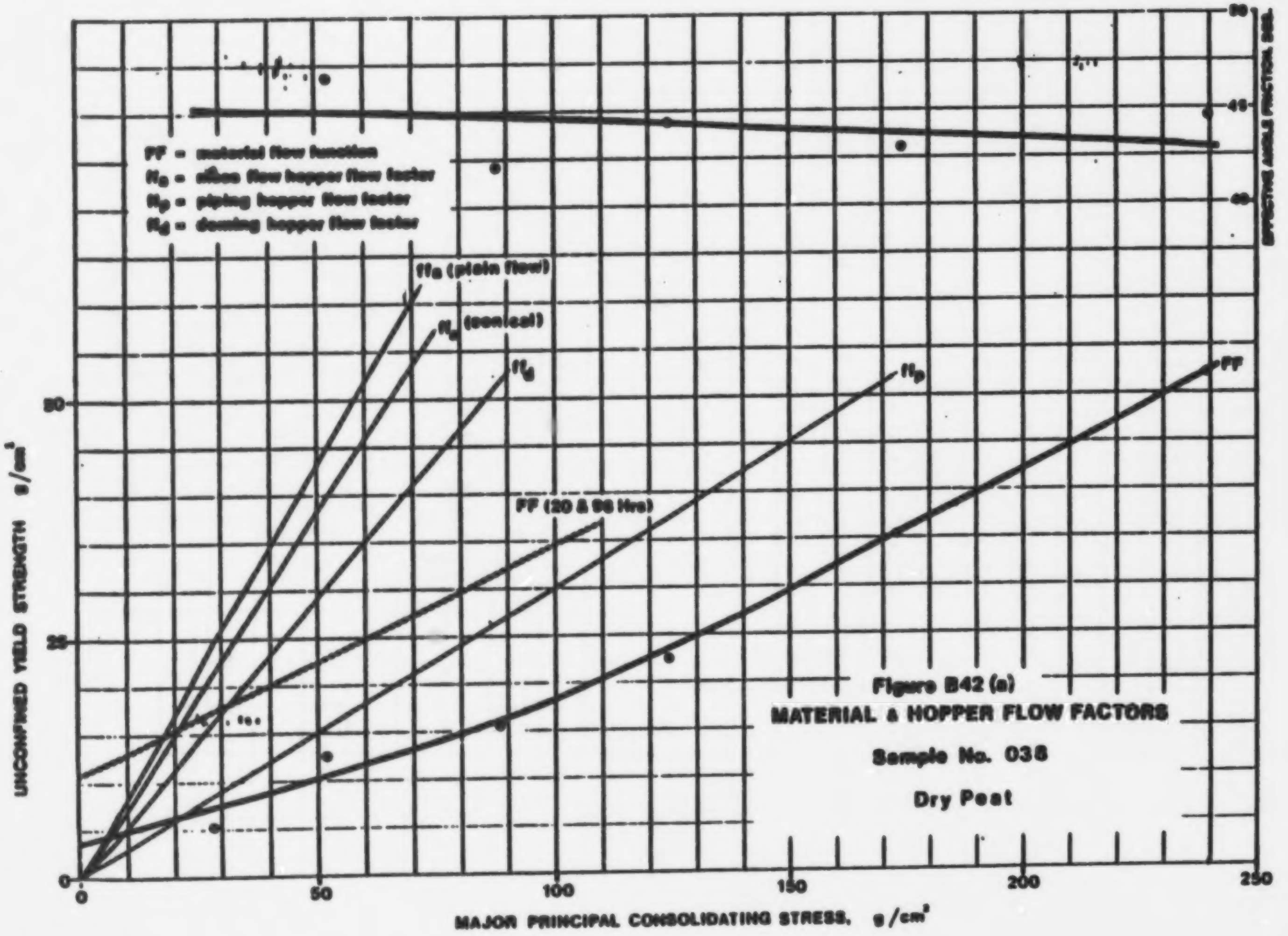

Figure B42 (a)

MATERIAL & HOPPER FLOW FACTORS

Sample No. 038

Dry Peat

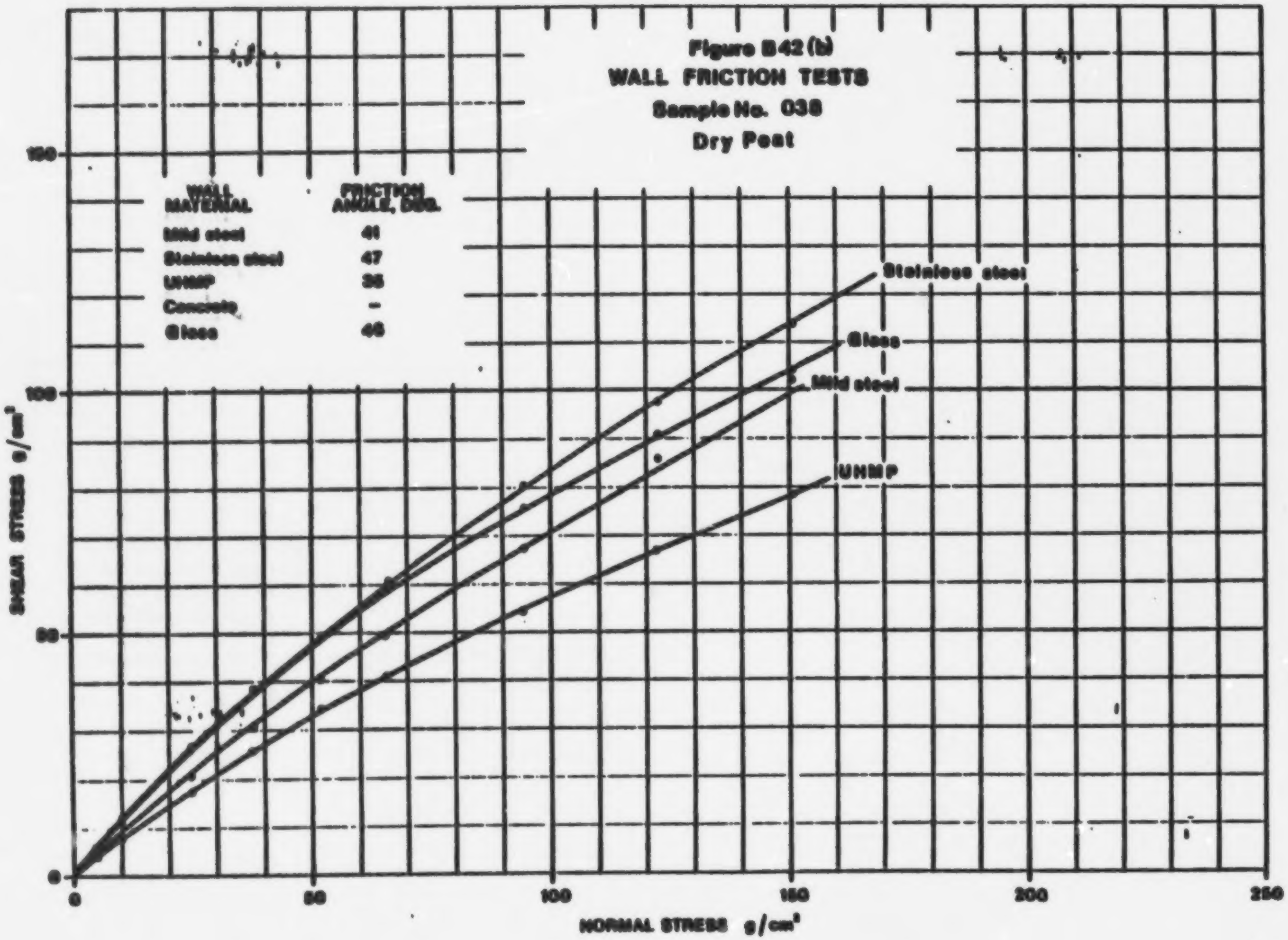

Figure B42 (b)
WALL FRICTION TESTS
Sample No. 038
Dry Peat

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	41
Stainless steel	47
UHMP	35
Concrete	–
Glass	45

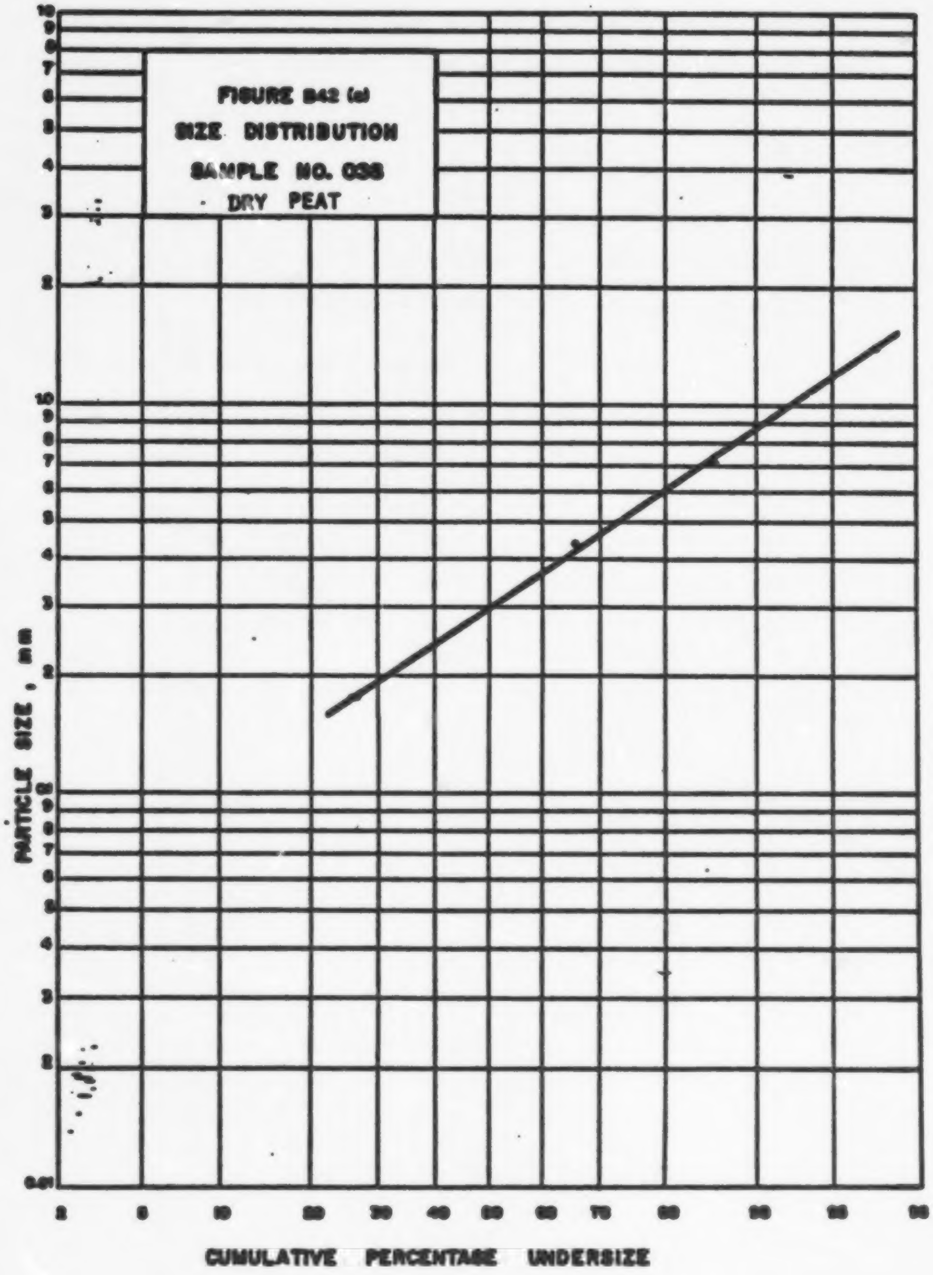

FIGURE B42 (a)
SIZE DISTRIBUTION
SAMPLE NO. 038
DRY PEAT

TABLE B43 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

MANITOBA PEAT (FISON'S WESTERN PEAT) SAMPLE # 039

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	13.8		
		1.5	3.7
		2.9	4.5
		4.3	6.2
		6.2	7.7
		11.8	12.1
		13.2	12.8
		14.6	13.8
24.3	23.0		
		1.5	4.7
		2.9	6.4
		4.3	8.3
		9.0	11.7
		14.6	16.5
		21.0	20.9
		24.3	23.0
45.0	42.0		
		1.5	4.9
		2.9	6.8
		4.3	8.8
		9.0	14.6
		18.2	24.8
		33.9	35.7
		45.0	42.0
60.3	56.2		
		1.5	6.0
		2.9	8.4
		4.3	9.3
		9.0	15.8
		24.3	32.2
		45.0	50.5
		60.3	56.2
85.6	83.5		
		1.5	7.9
		4.3	12.3
		24.3	33.6
		45.0	53.6
		60.3	66.0
		70.4	73.1
		85.6	83.5
115.9	103.6		
		1.5	7.4
		4.3	14.6
		24.3	41.5
		45.0	58.4
		70.4	78.0
		85.6	86.7
		115.9	103.6

TABLE B43 (b)

MANITOBA PEAT (FISON'S WESTERN PEAT) SAMPLE # 039 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION			FLOW PROPERTIES					
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	13.8	32.4	8.0	4.05	47.4	53.94	1.15	.43
24.3	23.0	54.6	13.8	3.95	47.8	53.94	1.99	.75
45.0	42.0	99.7	24.4	4.08	47.3	53.94	3.53	1.33
60.3	56.2	134.9	33.9	3.98	47.7	53.94	4.90	1.84
85.6	83.5	193.1	49.7	3.89	48.1	53.94	7.17	2.70
115.9	103.6	251.2	57.9	4.34	46.4	53.94	8.36	3.14

SHEAR INDEX (N) = 1.43

YIELD LOCUS	PERCENT FIT
1	99.9
2	99.9
3	99.8
4	99.6
5	99.9
6	99.8

TABLE B43 (c)

WALL FRICTION TEST RESULTS

DRY PEAT - MANITOBA (FISONS WESTERN) SAMPLE #039

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	147.3
150.3	133.6
122.2	114.7
94.1	91.9
66.1	73.1
52.0	60.3
38.0	48.1
24.0	33.5
9.9	14.4
4.7	6.9

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	133.7
150.3	115.6
122.2	94.7
94.1	75.8
66.1	53.3
52.0	42.8
38.0	31.1
24.0	18.9
9.9	7.6
4.7	4.4

WALL MATERIAL - PLASTIC COATING

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	132.6
150.3	121.2
122.2	106.7
94.1	88.5
66.1	67.1
52.0	51.9
38.0	38.2
24.0	23.9
9.9	10.7
4.7	4.6

TABLE B43 (c) con't

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	124.9
150.3	104.4
122.2	85.7
94.1	64.1
66.1	43.5
52.0	33.3
38.0	23.7
24.0	14.9
9.9	5.6
4.7	4.2

WALL MATERIAL - ULTRA HIGH MOLECULAR POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	109.7
150.3	96.3
122.2	82.1
94.1	66.7
66.1	49.5
52.0	40.3
38.0	30.9
24.0	20.3
9.9	9.2
4.7	4.6

WALL MATERIAL - GLASS

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.3	98.2
150.3	88.4
122.2	80.0
94.1	66.7
66.1	48.1
52.0	41.8
38.0	34.7
24.0	25.5
9.9	13.1
4.7	4.2

TABLE B43 (d)

COMPUTER ANALYSIS OF STORAGE AT REST

MANITOBA PEAT SAMPLE B-039

- TIME CONSOLIDATION RESULTS

CONSOLIDATION		YIELD POINT		<——FLOW PROPERTIES——>						
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS		UNCONFIN YIELD STRESS	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION
				INST	TIME				
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		G/SQ CM	DEG	DEG	G/SQ CM
CONSOLIDATION PERIOD 90 HOURS									
24.3	21.0	24.3	28.6	54.6	65.8	26.1	55.2	53.9	3.77

SHEAR INDEX (N) = 1.43

COHESION/ TENSILE
STRENGTH = 2.66

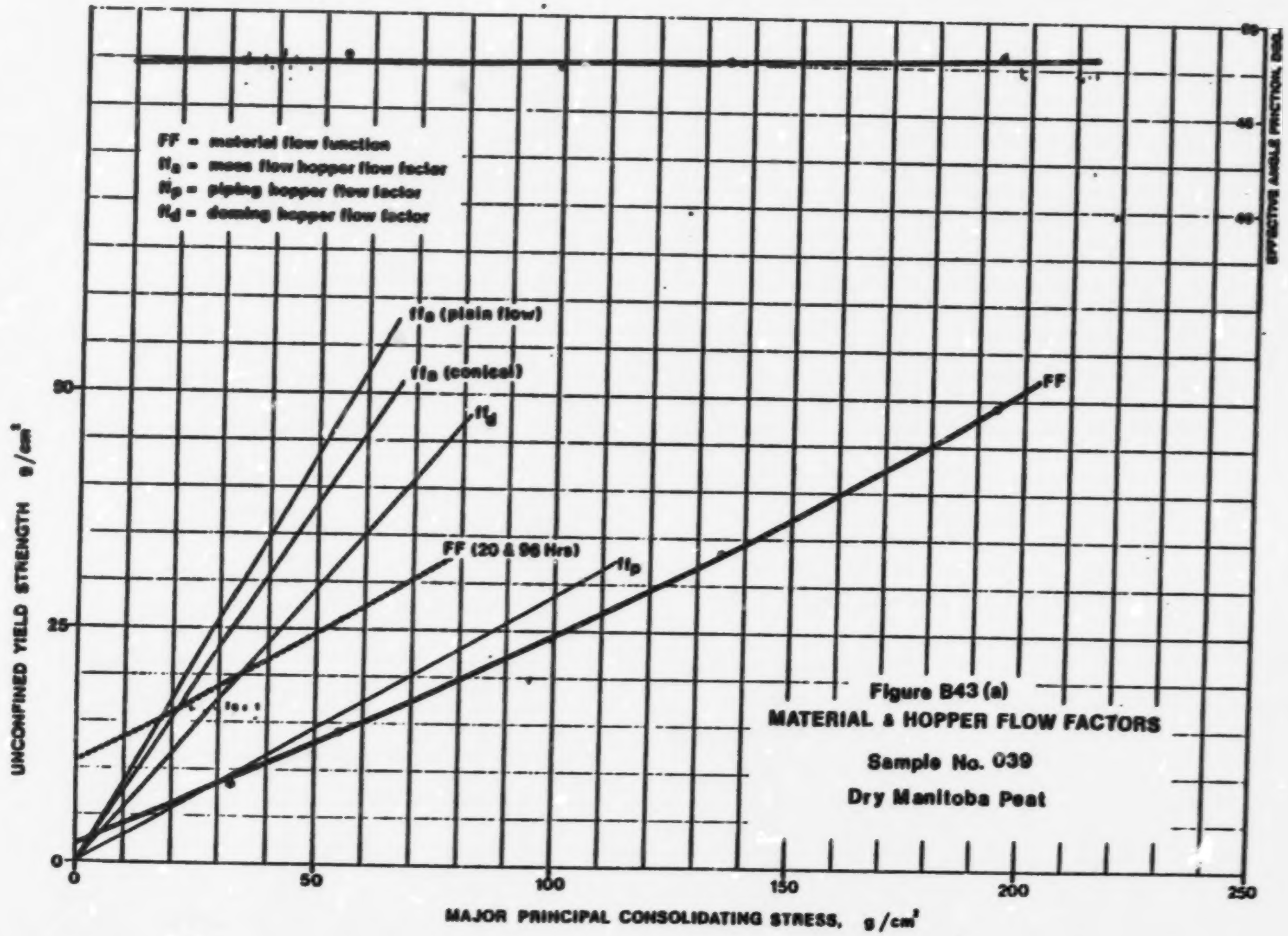

Figure B43 (a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 039
Dry Manitoba Peat

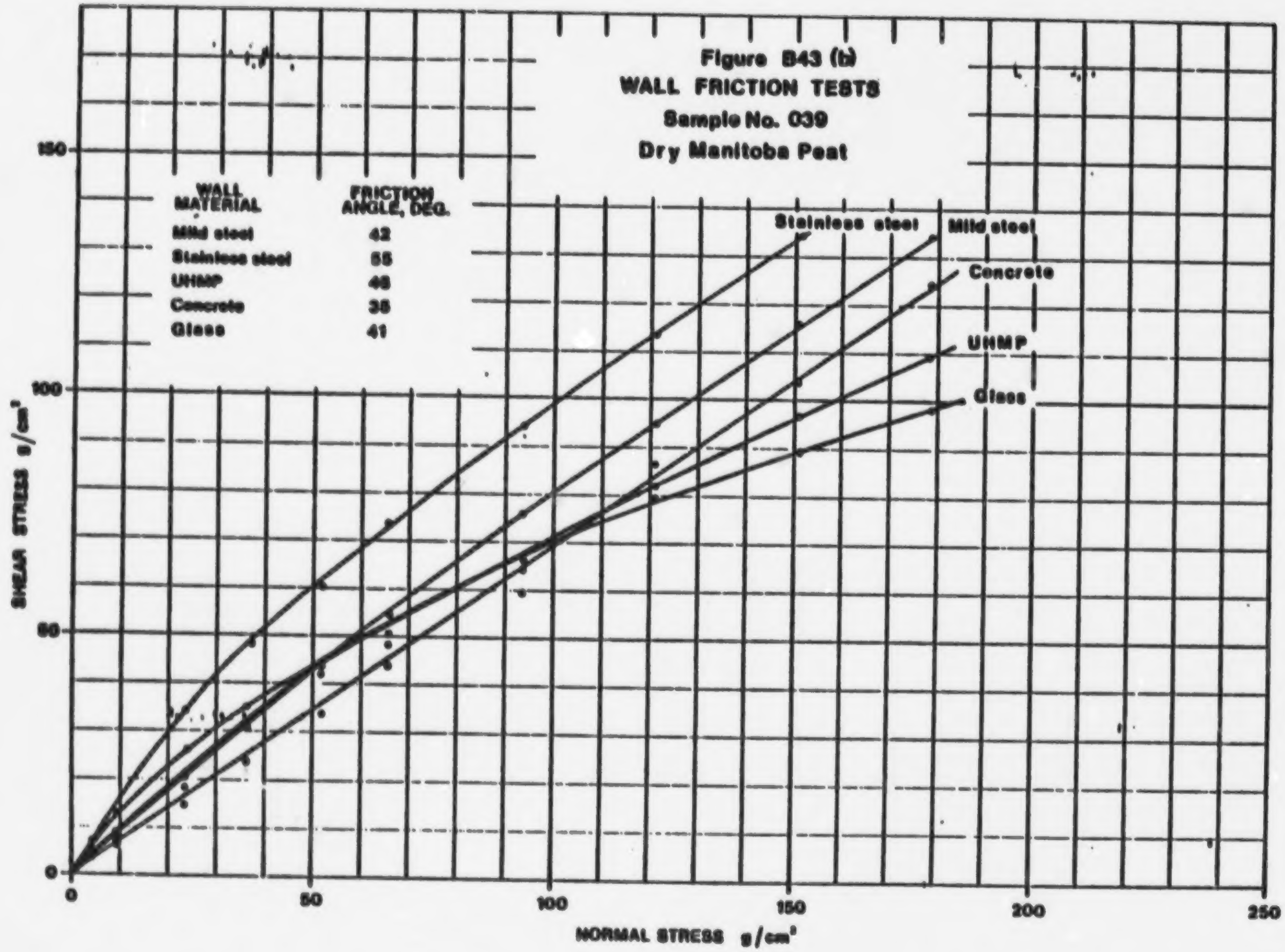

Figure B43 (b)
WALL FRICTION TESTS
Sample No. 039
Dry Manitoba Peat

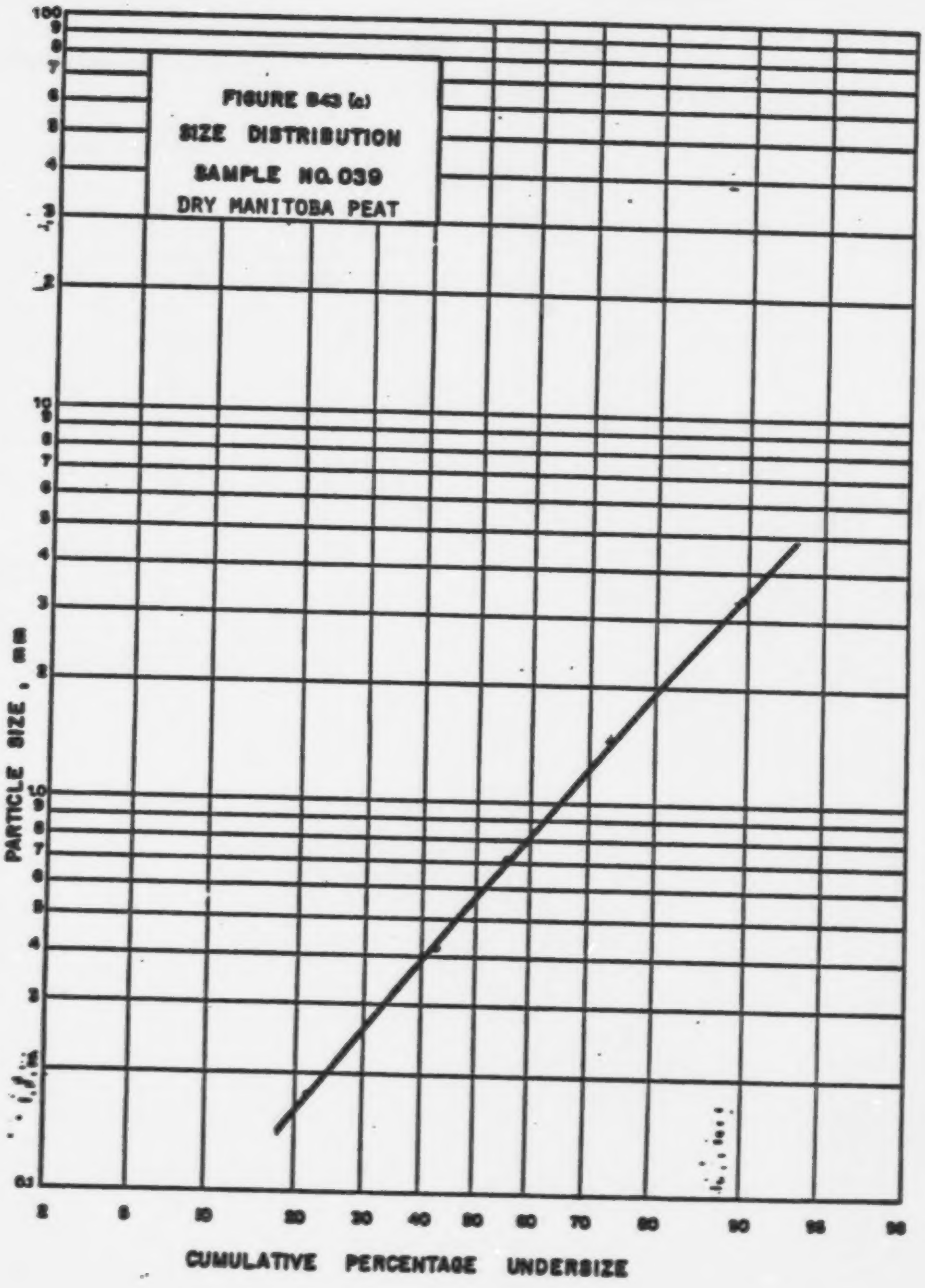

FIGURE B43 (a)
SIZE DISTRIBUTION
SAMPLE NO. 039
DRY MANITOBA PEAT

TABLE B44 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

GRAIN DUST-SCREENED SAMPLE #023

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM	NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
14.6	11.7		
		1.5	3.9
		2.9	5.3
		4.3	6.2
		6.2	7.6
		11.8	10.9
		13.2	11.3
		14.6	11.7
24.3	19.1		
		1.5	3.8
		2.9	5.0
		4.3	6.9
		9.0	11.2
		14.6	14.7
		21.0	17.6
		24.3	19.1
45.0	33.3		
		1.5	4.9
		2.9	6.1
		4.3	7.1
		9.0	11.3
		18.2	17.9
		33.9	27.9
		45.0	33.3
60.3	44.1		
		1.5	6.4
		2.9	8.6
		4.3	10.0
		9.0	14.7
		24.3	23.8
		45.0	35.3
		60.3	44.1
85.6	58.4		
		1.5	6.7
		4.3	10.0
		24.3	27.5
		45.0	40.2
		60.3	47.2
		70.4	54.0
		85.6	58.4
115.9	78.0		
		1.5	6.4
		4.3	9.3
		24.3	28.1
		45.0	42.5
		85.6	67.1
		115.9	78.0
		115.9	78.0

TABLE B44 (b)

GRAIN DUST-SCREENED SAMPLE 0023 (CONT)

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
14.6	11.7	28.7	10.1	2.83	44.8	45.41	1.82	.80
24.3	19.1	45.9	14.3	3.17	42.7	45.41	2.61	1.15
45.0	33.3	79.6	20.4	3.89	39.1	45.41	3.68	1.62
60.3	44.1	106.7	27.4	3.89	39.1	45.41	4.94	2.18
85.6	58.4	148.2	35.4	4.19	37.9	45.41	6.38	2.81
115.9	78.0	197.1	44.1	4.47	36.9	45.41	7.94	3.50

SHEAR INDEX (N) = 1.55

YIELD LOCUS	PERCENT FIT
1	99.8
2	99.8
3	99.6
4	99.9
5	99.9
6	99.7

TABLE B44 (c)

GRAIN DUST-SCREENED SAMPLE #023

WALL FRICTION TEST RESULTS

GRAIN DUST-SCREENED SAMPLE #044

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	82.8
150.4	70.2
122.4	56.1
94.3	43.5
66.2	29.9
52.2	24.1
38.2	17.8
24.1	11.5
10.1	5.2
4.9	2.5

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	31.9
150.4	29.9
122.4	23.9
94.3	18.7
66.2	14.0
52.2	10.8
38.2	8.4
24.1	5.6
10.1	2.4
4.9	1.4

TABLE B44 (c) con't

WALL MATERIAL - CONCRETE

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	99.1
150.4	82.8
122.4	68.1
94.3	51.6
66.2	38.9
52.2	30.2
38.2	22.2
24.1	14.6
10.1	7.3
4.9	3.5

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
178.5	39.3
150.4	33.0
122.4	26.4
94.3	20.1
66.2	14.6
52.2	11.4
38.2	8.7
24.1	5.8
10.1	2.5
4.9	1.4

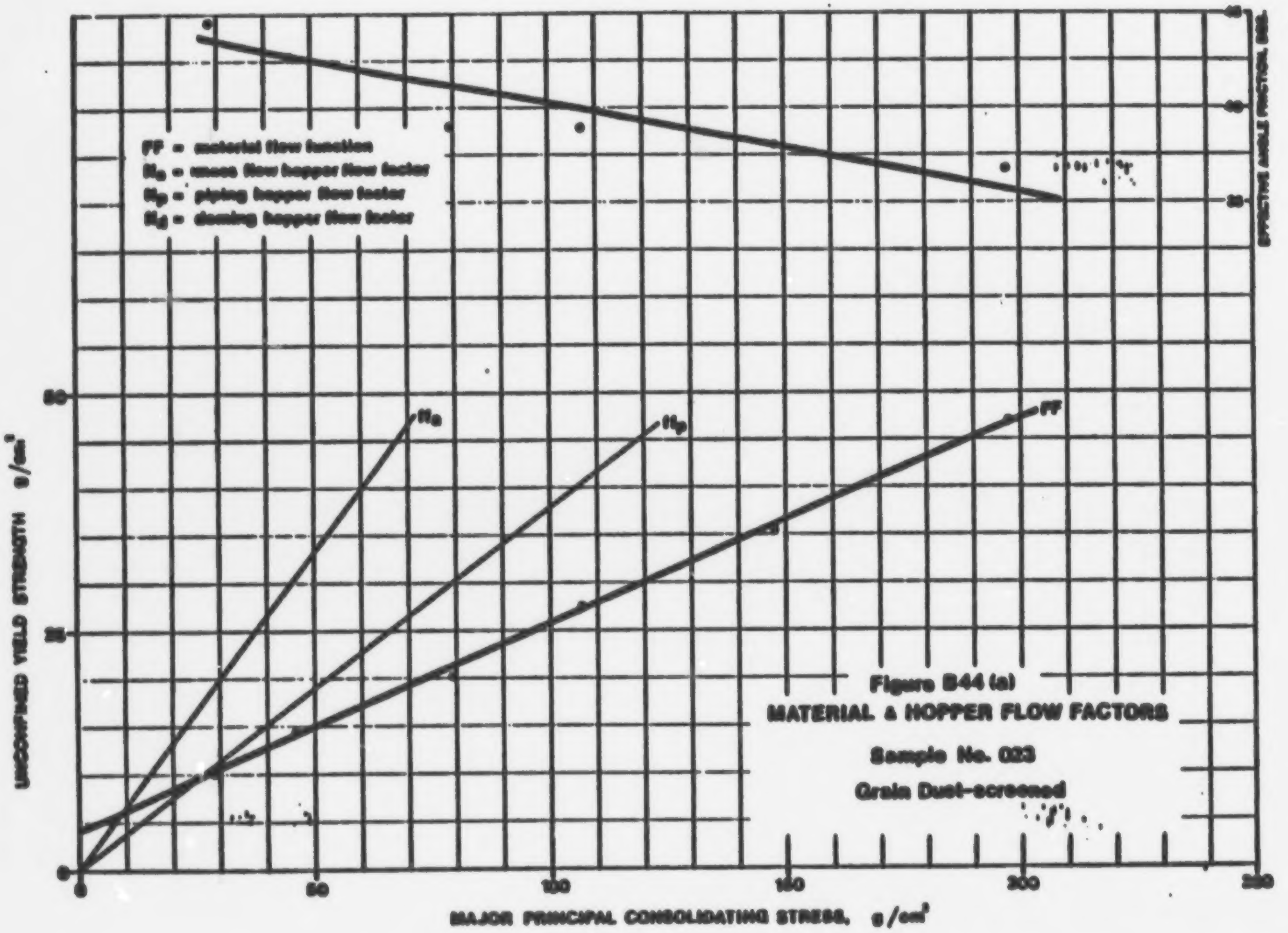

Figure B44 (a)
MATERIAL & HOPPER FLOW FACTORS
Sample No. 023
Grain Dust-screened

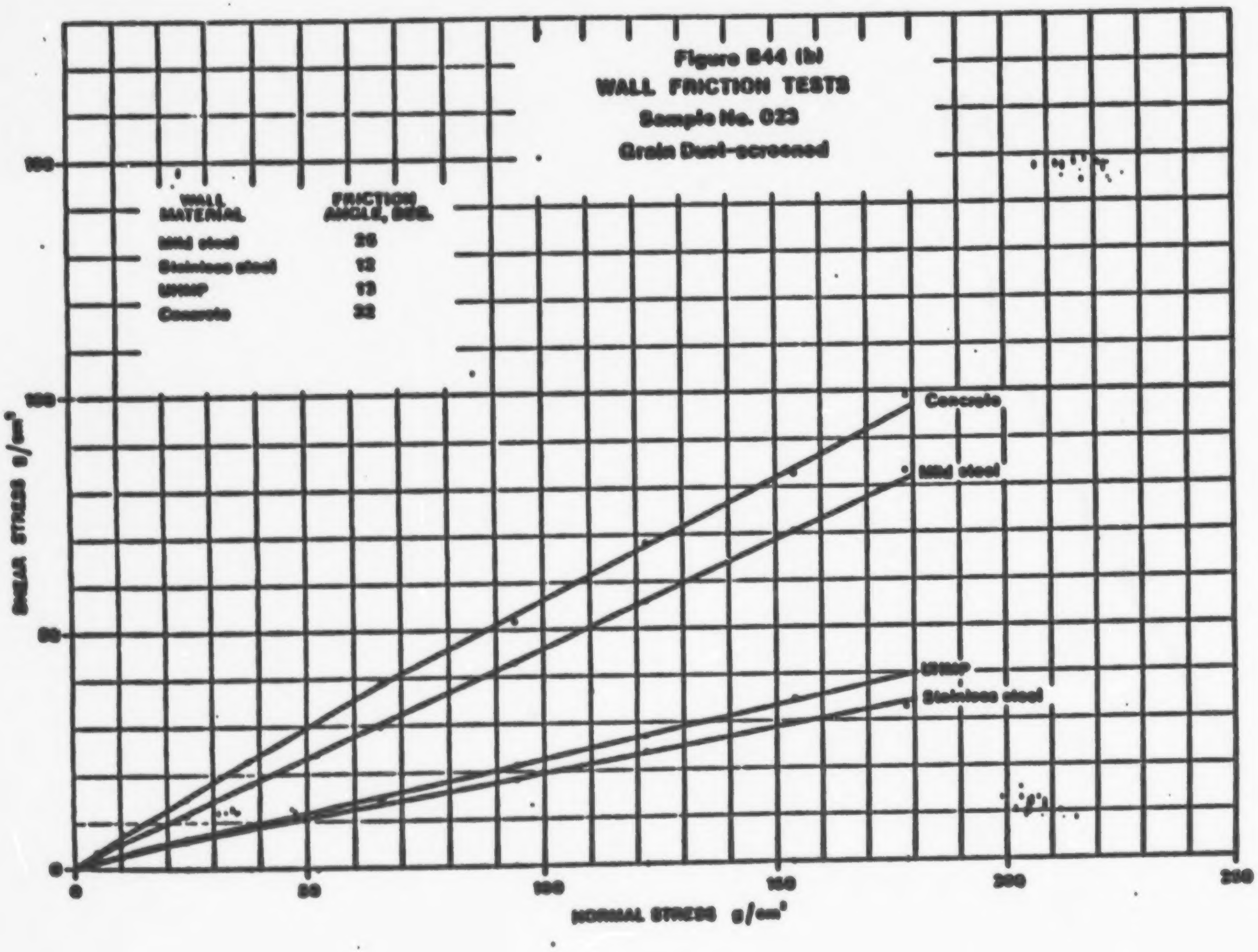

Figure B44 (b)
WALL FRICTION TESTS
Sample No. 023
Grain Dust-screened

WALL MATERIAL	FRICTION ANGLE, DEG.
Mild steel	26
Stainless steel	12
UHMP	13
Concrete	32

TABLE B45 (a)

COMPUTER ANALYSIS OF FLOW PROPERTIES

PELLETIZED GRAIN DUST SAMPLE #023-A

- SHEAR TEST RESULTS

CONSOLIDATION		YIELD	
NORMAL STRESS	SHEAR STRESS	NORMAL STRESS	SHEAR STRESS
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM
27.0	22.7		
		2.5	6.9
		4.2	7.6
		8.4	14.5
		12.6	16.7
		16.8	17.2
		24.4	19.3
		27.0	22.7
48.1	37.8		
		4.2	9.7
		8.4	15.6
		16.8	20.9
		27.0	27.1
		33.7	28.4
		39.6	33.8
		48.1	37.8
59.9	46.8		
		4.2	7.1
		8.4	15.6
		16.8	24.1
		27.0	31.8
		43.8	44.1
		56.5	44.3
		59.9	46.8
81.8	67.6		
		4.2	7.5
		12.6	17.2
		27.0	30.3
		56.5	50.3
		59.9	56.2
		73.4	63.8
		81.8	67.6
98.7	80.6		
		4.2	11.0
		12.6	23.0
		27.0	40.2
		56.5	64.3
		73.4	76.1
		90.3	74.4
		98.7	80.6
115.6	93.1		
		4.2	10.2
		12.6	26.5
		27.0	39.3
		56.5	63.3
		81.8	78.6
		107.1	89.2
		115.6	93.1

TABLE B45 (b)

PELLETIZED GRAIN DUST SAMPLE #023-A

- FLOW PROPERTIES OF MATERIAL

CONSOLIDATION				FLOW PROPERTIES				
NORMAL STRESS	SHEAR STRESS	MAJ PRINC CONSOL'N STRESS	UNCONFIN YIELD STRESS	FLOW FUNC	EFFECT FRIC ANGLE	INTERNAL FRIC ANG AT FREE SURFACE	COHESION	TENSILE STRENGTH
G/SQ CM	G/SQ CM	G/SQ CM	G/SQ CM		DEG	DEG	G/SQ CM	G/SQ CM
27.0	22.7	53.0	20.5	2.59	45.7	45.69	3.58	1.41
48.1	37.8	89.1	29.5	3.02	42.5	45.69	5.15	2.02
59.9	46.8	112.8	39.1	2.89	43.4	45.69	6.82	2.68
81.8	67.6	152.7	51.5	2.96	42.9	45.69	8.99	3.53
98.7	80.6	191.4	71.5	2.68	45.0	45.69	12.47	4.90
115.6	93.1	218.4	76.3	2.86	43.6	45.69	13.30	5.23

SHEAR INDEX (N) = 1.62

YIELD LOCUS	PERCENT FIT
1	98.7
2	99.8
3	99.1
4	98.9
5	99.1
6	99.5

TABLE B45 (c)

WALL FRICTION TEST RESULTS

PELLETIZED GRAIN DUST SAMPLE #023-A

WALL MATERIAL - MILD STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
78.0	24.7
69.5	22.2
61.0	19.0
52.6	16.1
44.2	13.6
35.8	11.1
27.3	8.8
18.8	5.9
10.3	3.2
5.9	1.8

WALL MATERIAL - STAINLESS STEEL

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
78.0	17.0
69.5	13.1
61.0	11.3
52.6	9.7
44.2	8.2
35.8	6.7
27.3	5.2
18.8	3.6
10.3	2.0
5.9	1.2

WALL MATERIAL - ULTRA HIGH MOL. POLYMER

NORMAL STRESS G/SQ CM	SHEAR STRESS G/SQ CM
78.0	18.5
69.5	15.8
61.0	13.6
52.6	11.5
44.2	9.5
35.8	7.4
27.3	5.6
18.8	3.9
10.3	2.3
5.9	1.4

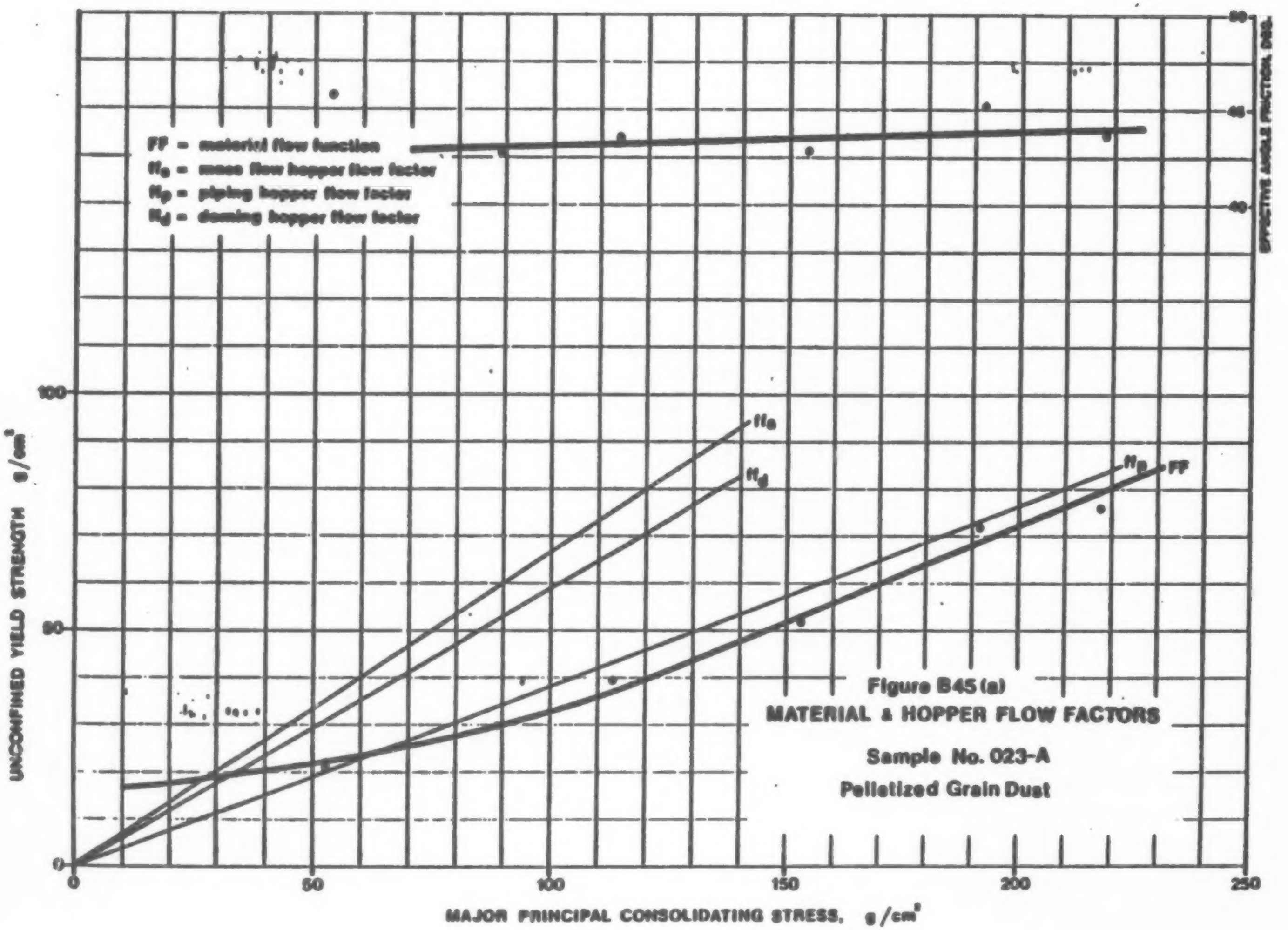

Figure B45 (a)
MATERIAL & HOPPER FLOW FACTORS

Sample No. 023-A
Pelletized Grain Dust

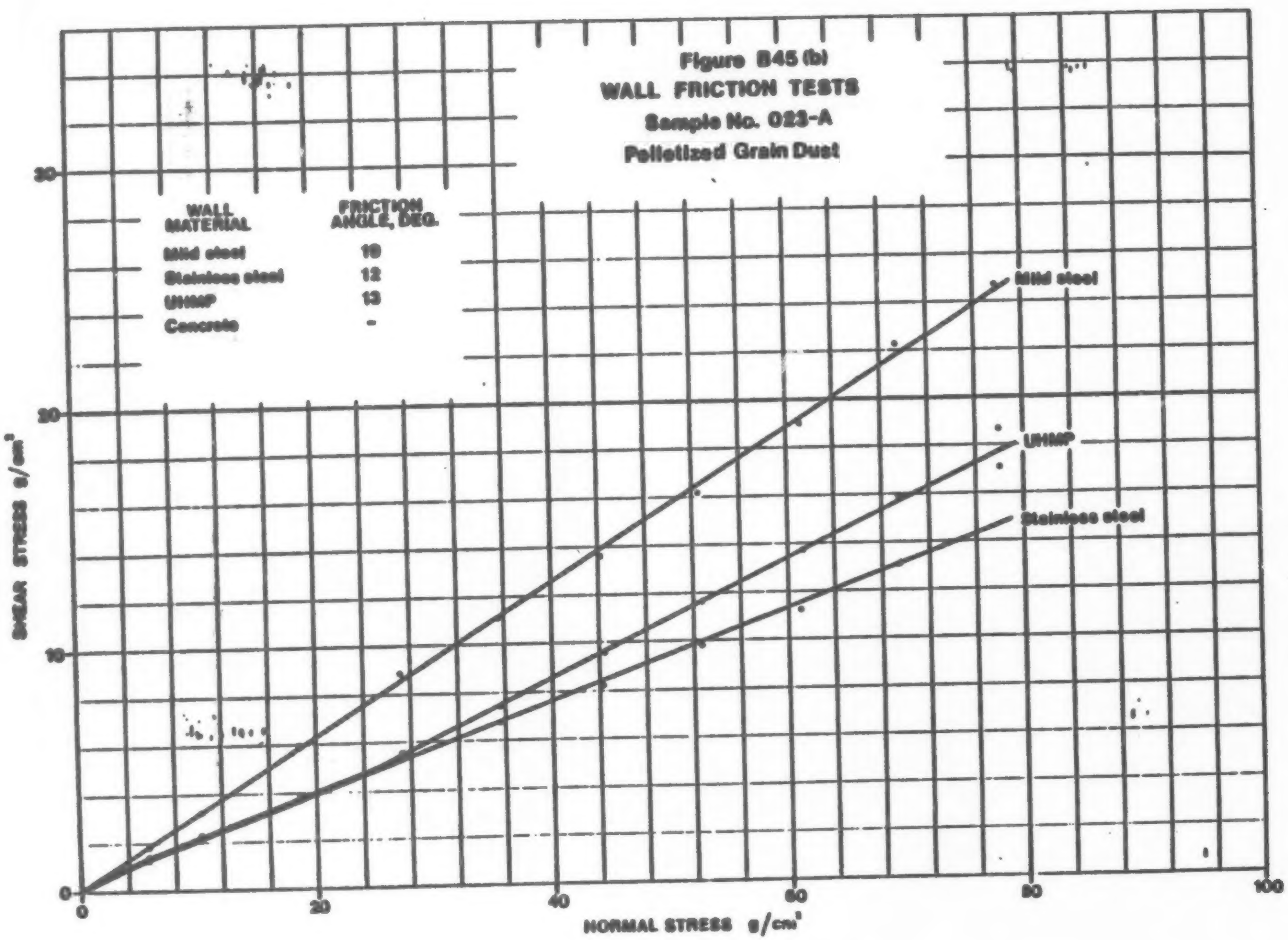

Figure B45 (b)
WALL FRICTION TESTS
Sample No. 023-A
Pelletized Grain Dust

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